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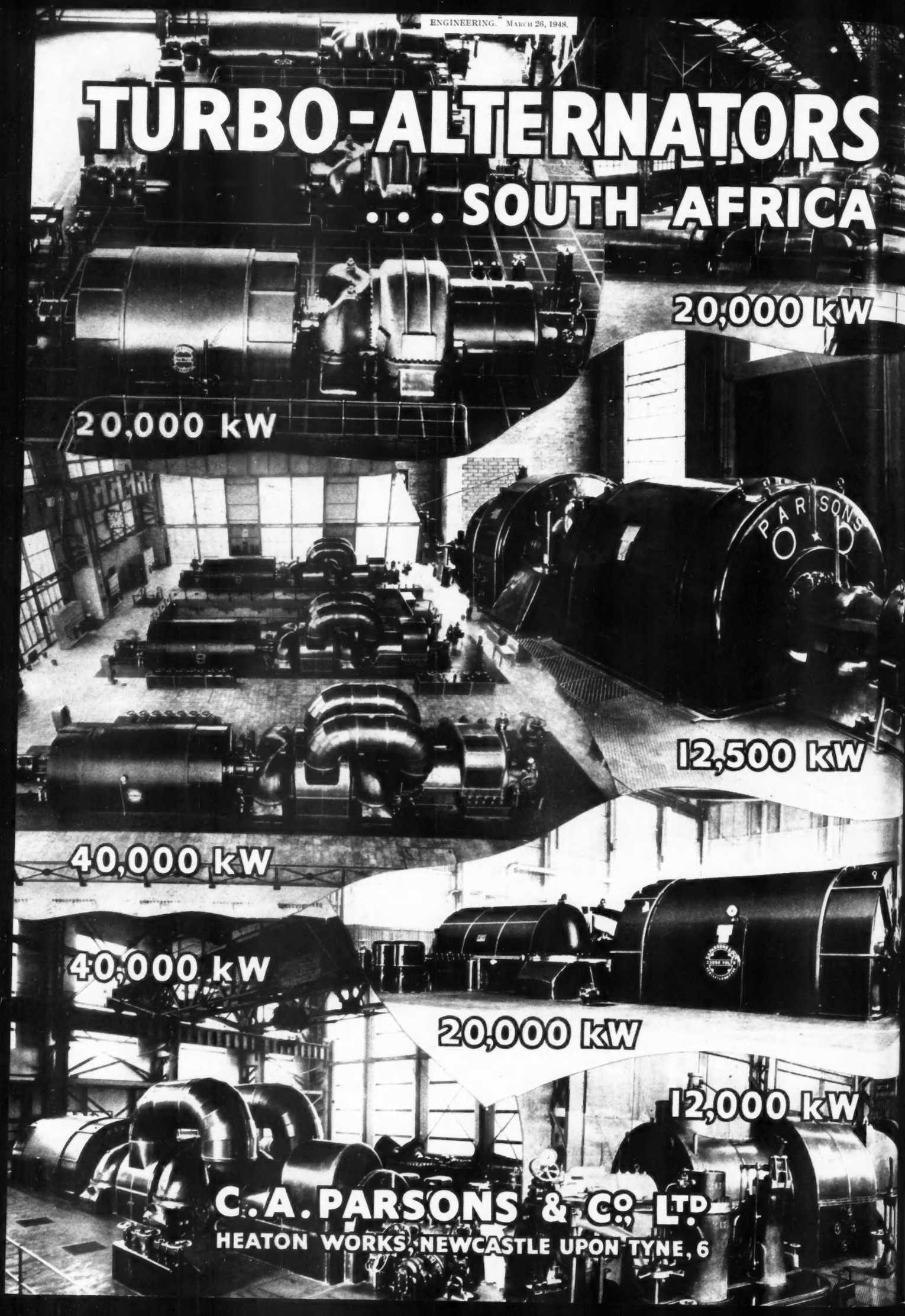
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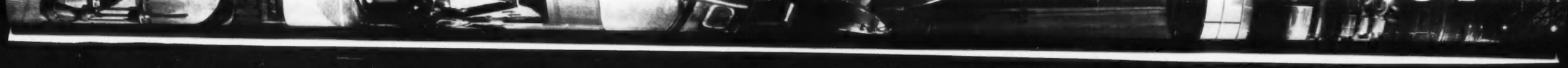

A THEORY OF STATIC AND DYNAMIC HARDNESS.

By D. TABOR.

THE hardness of a metal is often defined as its resistance to indentation. In the Brinell hardness test, a hard steel ball is pressed under a fixed normal load on to the smooth surface of the metal to be tested. When equilibrium has been reached, the load and indenter are removed, and the diameter of the permanent impression measured. The hardness is then expressed as the ratio of the load to the curved area of the indentation (Brinell hardness) or as the ratio of the load to the projected area of the indentation (Meyer hardness). In both cases, the hardness has the dimensions of pressure.

For a spherical indenter it is found empirically that the diameter d of the permanent impression formed is related to the load F by a relation of the type

$$F = k d^n, \quad . \quad . \quad . \quad (1)$$

where k and n are suitable constants. For almost all metals n lies between 2 and 2·5 and is a measure of the degree of work hardening of the material. For fully annealed metals it is nearly 2·5, while for highly worked metals it approaches a value of 2. If balls of various diameters are used, equations similar to (1) are obtained. The index n for a given metal specimen remains almost unchanged but the constant k varies with the ball diameter D in such a way that $k D^{n-2}$ is a constant. This empirical relation was first deduced by Meyer in 1908 and an enormous number of hardness measurements since that time have confirmed its validity and the validity of equation (1) over a very wide range of experimental conditions. If conical or pyramidal indenters are used a relation similar to equation (1) is obtained. It is found, however, that although the constant k depends on the angle of the indenter, the index n is equal to 2 over a very wide range of loads and indenterangles.

When an indentation is made in a metal surface with a hard spherical indenter, it is found that the indentation remaining when the load is removed is spherical in form but of a larger radius of curvature than that of the indenter. This effect, which is referred to in the English literature as "shallowing," has been loosely ascribed to the release of elastic stresses in the material surrounding the indentation. It is clear, however, that if this is a truly elastic effect, it should be reversible, i.e., if the indenter is replaced in the recovered indentation and the original load applied, the surfaces should deform elastically, and, on removing the load, the diameter and curvature of the recovered indentation should be unchanged.

Experiments were carried out to test this. Impressions were made with hard-steel balls of various diameters on various metal surfaces, using loads ranging from 250 kg. to 3,000 kg. The diameters d of the impressions formed were measured after 1, 2, 3 and 5 cyclic applications of the load. The radius of curvature r_2 of the indentation was also measured, using a delicate profilometer, and a metallographic section across the diameter of the indentation. The results show that the diameter and curvature of the indentation remain almost unaltered after two or three cyclic applications of the load. This means, in effect, that the "recovery" of the indentation is reversible and therefore elastic. Consequently, the classical laws of elasticity may be applied to this portion of the deformation process. We idealise the condition of the surface of the metal after the indentation has been formed, and assume it to consist of a plane surface containing a depression of spherical form of radius of curvature r_2 and of diameter $d = 2a$ (Fig. 1). When a hard-steel sphere (radius of curvature r_1) is placed in the indentation, and a normal force of F dynes is applied, both surfaces are elastically deformed and finally touch over the boundaries of the indentation (Fig. 2). We assume that there is very little change in the diameter d during this deformation, an assumption which is generally accepted as being valid to within a few per cent. Then, according to Hertz's celebrated equations describing the elastic deformation of spherical surfaces, the relation between F, d, r_1 and r_2 is given by

$$d = 2a - 2{\cdot}22 \left[\frac{F}{2} \frac{r_1 r_2}{r_2 - r_1} \left(\frac{1}{E_1} + \frac{1}{E_2} \right) \right]^{\frac{1}{3}}, \quad (2)$$

where E_1, E_2 are Young's moduli for the indenter and the metal, and where a value of 0·3 has been assumed for Poisson's ratio. In a discussion of the derivation of this equation, Prescott has indicated that even if the surface X A B Y is not a plane, the same equation will result. If, for example, the surface rises at the regions A and B or falls, the above equation is still valid, provided the projections or depressions at A and B are not too marked.

Apply this equation to the previous measurements of r_1, r_2, F and d, and compare the value of d obtained from equation (2) with the observed value of the diameter of the recovered impression. The results are given in Table I. It is seen that the agreement between the last two columns is reasonably good, particularly as the accuracy in determining r_2 was not better than about 4 per cent. Table I also contains results from other authors. It is seen that, in general, the agreement between the observed and calculated values of d is reasonably good, particularly when r_2 is not too close to r_1, i.e., when the elastic "recovery" is marked. It is, of course, true that as the calculation of d involves a cube root, the values of F, r_1, r_2, E_1 and E_2 are not very critical. Nevertheless, the agreement is consistent for a great diversity of materials and experimental conditions.

The experiments show that when an indentation is formed in a metal surface by a hard spherical indenter, the last stage of the indentation process is reversible and may be expressed in terms of the elastic constants of the material and the sphere. Until this stage is reached, however, there will generally be appreciable plastic flow of the metal. This can only occur if the stresses within the indentation exceed the elastic limit of the material. We may, therefore, put forward the following mechanism for the processes involved in the Brinell hardness test. When the ball presses on to the

Fig. 1.

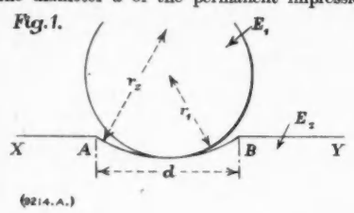

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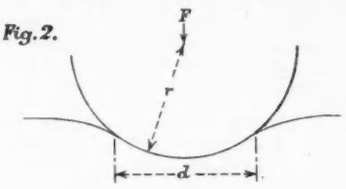
Fig. 2.



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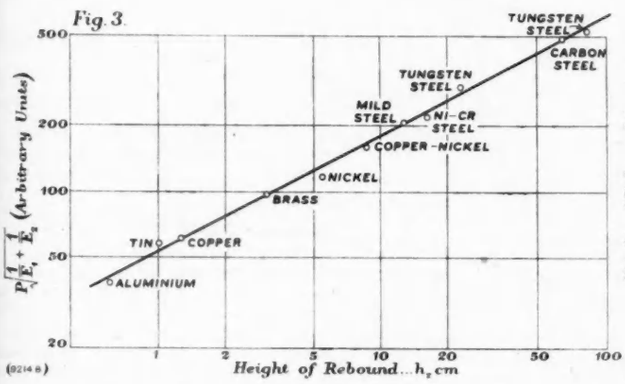

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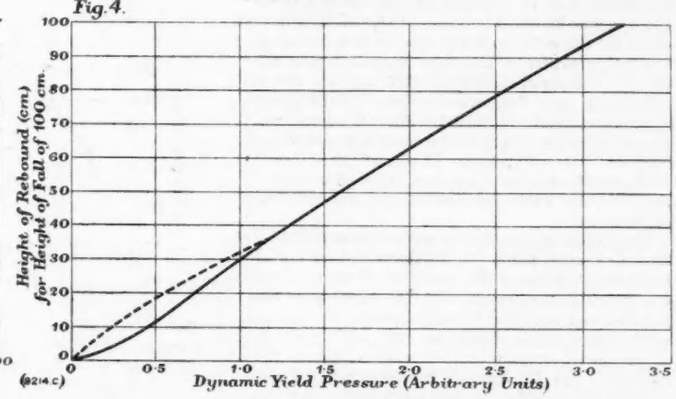
Fig. 4.



(9214.C.)

TABLE I—ELASTIC "RECOVERY" OF BRINELL IMPRESSIONS.

Material.	Assumed Value of E_2, Dynes per sq. cm.	Load, kg.	Observed Values in cm. r_1.	Observed Values in cm. r_2	Observed Values in cm. d.	Calculated d cm.
Brass	$10 \cdot 10^{11}$	250	0·5	0·64	0·160	0·17
		500	0·952	1·21	0·27	0·26
Aluminium alloy	$7 \cdot 10^{11}$	250	0·5	0·66	0·178	0·18
		500	0·952	1·15	0·26	0·30
Mild steel	$20 \cdot 10^{11}$	500	0·5	0·605	0·183	0·20
Hardened steel	$20 \cdot 10^{11}$	1,000	0·5	0·677	0·202	0·22
		3,000	0·952	1·39	0·330	0·36
		3,000	1·59	2·80	0·370	0·39
Ni-Cr steel*	$20 \cdot 10^{11}$	3,000	0·5	0·627	0·324	0·34
Manganese steel		3,000	0·5	0·569	0·407	0·41
Rail steel		3,000	0·5	0·537	0·445	0·49
Soft brass†	$9 \cdot 10^{11}$	500	0·5	0·521	0·330	0·38
Soft bronze	$7 \cdot 5 \cdot 10^{11}$	500	0·5	0·557	0·276	0·28
0·5 C - W steel	$20 \cdot 10^{11}$	3,000	0·5	1·03	0·26	0·26
0·9 C - W steel		3,000	0·5	1·732	0·240	0·23
Quenched carbon steel	$20 \cdot 10^{11}$	745	0·5	2·25	0·147	0·14
		1,245	0·5	1·89	0·174	0·17
		1,745	0·5	1·56	0·193	0·19
		2,745	0·5	1·36	0·232	0·23

* R.G.C. Batson. *Proc. I. Mech. E.*, vol. 2, page 463 (1918).
† Foss and Brumfield. *Proc. A.S.T.M.*, vol. 22, page 312 (1922).

surface the metal is first deformed elastically. The stresses, however, soon exceed the elastic limit of the metal and plastic flow occurs. As the metal is displaced, work hardening occurs and the elastic limit of the material increases. This process continues until the stresses are now distributed over an impression of such dimensions that the stresses are within the elastic limit of the deformed material. If, for example, the load is removed, there is elastic "recovery," and if the same load is reapplied to the recovered indentation, the surfaces deform elastically until they just fit over the diameter of the original impression. If, now the load is further increased, the stresses exceed the elastic limit and further flow of the material occurs. There is a further increase in work hardening and the process continues until the stresses are distributed over a larger impression and so fall again within the increased elastic limit.

If a hard-steel or diamond indenter is dropped on to a metal surface, it rebounds to a certain height and also leaves an indentation in the surface. Martel showed that, over a wide range of experimental conditions, the volume of the indentation so formed is directly proportional to the energy of the indenter. This may be interpreted as implying that the metal offers a constant pressure of resistance to the indenter equal numerically to the ratio $\frac{\text{energy of indenter}}{\text{volume of indentation}}$. This ratio has the dimensions of pressure, and is referred to as the dynamic hardness number. Later workers have discussed the validity of this relation in some detail, and in particular it has been suggested that the energy of rebound should be taken into account in calculating the dynamic hardness. A different approach is that adopted in Shore's scleroscope, where the height of rebound is used as a measure of hardness. It is found that if the height of fall is constant, the height of rebound is roughly proportional to the static hardness of the material concerned.

The process of impact may be conveniently divided into three main parts. (i) At the initial instant of impact the surface of the metal and of the indenter are elastically deformed. (ii) The stresses in the metal exceed its elastic limit and plastic flow occurs while further elastic stresses are built up in the bulk of the metal around the indentation and in the indenter. (iii) The indenter is now brought to rest, and there is a release of elastic stresses in both the indenter and the metal. These stresses are responsible for the rebound observed. Andrews, who was mainly concerned with the time of the whole collision process, has analysed the three main parts, though his calculations of the last two parts are admittedly of an approximate nature. Since we are here concerned mainly with the forces involved in the collision process, a different approach, which provides a much simpler solution, may be adopted.

Consider the case of an indenter of mass m possessing a spherical tip of radius of curvature r_1 which falls from a height h_1 on to a flat metal surface. After the collision, the indenter rebounds to a height h_2 and leaves a permanent indentation in the metal surface, of diameter $d = 2a$ and of volume V_r. It is first assumed that there is a dynamic yield pressure P which, to a first approximation, is constant and is not necessarily the same as the static pressure required to cause plastic flow. Thus as soon as the pressure reaches a value P, plastic flow of the metal occurs and flow continues at this pressure until the indenter is brought to rest. Then the work done as plastic energy in producing a permanent indentation of volume V_r is, by definition of P, equal to $P V_r$. This is equal to the energy lost by the indenter so that

$$mgh_1 - mgh_2 = P V_r. \quad . \quad . \quad (3)$$

Since there has been elastic "recovery" of the indentation its radius of curvature will not be r_1 but something bigger, say r_2. Hence, to a first approximation, $V_r = \frac{\pi a^4}{4r_2}$. Now in practice it is very inconvenient to have to measure the true radius of curvature of the recovered indentation, but r_2 may be eliminated in the following way.

Assume that the mechanism involved in the dynamic indentation is essentially the same as that which occurs under static conditions; that is to say, if the indenter were replaced in the recovered indentation and a suitable load F applied for a very short interval of time, it would deform the indentation and itself elastically and just touch over the boundaries of the indentation where again the relations between d, F, r_1 and r_2 are given by equation (2). In this case, however, F, which corresponds to the force at this end of the indentation process, is equal to $P \pi a^2$. This gives one relation for expressing r_2 in terms of other parameters. We have

$$mgh_1 - mgh_2 = \frac{P \pi a^4}{4r_2} = \frac{P \pi a^4}{4r_1} - 1{\cdot}7\, P^2 a^3 \left(\frac{1}{E_1} + \frac{1}{E_2}\right). \quad . \quad (4)$$

The second step is to consider the elastic energy stored up in the process of pressing the indenter into the recovered indentation under the force F, which reaches a value $P \pi a^2$ at the end of the process. This energy is assumed to be equal to the energy released when the surfaces recover elastically, so that it is equal to the energy of rebound. A simple integration shows that this energy, which we equate to the rebound energy, is given by

$$mgh_2 = 2{\cdot}7\, P^2 a^3 \left(\frac{1}{E_1} + \frac{1}{E_2}\right). \quad . \quad (5)$$

It is seen from equation (4) that the first term on the right-hand side is equal to $P V_a$, where V_a is the apparent volume of the indentation which would be obtained if the indentation were considered to have the same radius of curvature as the indenter. The second term, by comparison with equation (5), is seen to be equal to $\frac{5}{8} mgh_2$.

Hence,

$$mgh_1 - mgh_2 = P V_a - \frac{5}{8} mgh_2$$

or

$$P = \frac{mg\left(h_1 - \frac{3}{8} h_2\right)}{V_a}. \quad . \quad . \quad (6)$$

It is at once apparent that if the rebound is not very large (so that h_1 is small), the results will not be very different from the early equation given by Martel, $P = \frac{mgh_1}{V_a}$ nor from the equation suggested by later workers, $P = \frac{mg(h_1 - h_2)}{V_a}$.

The validity of this analysis depends on the assumption that the internal forces occurring in the actual impact are essentially the same as those involved in the analytical model just described. In particular, we assume that the energy lost as elastic waves is negligible and that the temperature rise in the material around the indentation during impact is small and has a negligible effect on the strength properties of the metal.

In the above analysis P has been assumed to be constant. In practice there are two reasons why P may be expected to vary during the course of the impact. Firstly, there is a dynamic effect, analogous to a viscosity factor which makes P higher at the beginning of the indentation process where the rate of deformation of the material is a maximum. This effect is discussed later; it is, however, difficult to allow for it quantitatively. Secondly, work-hardening proceeds as the indentation is formed, so that we may expect an increase

STATIC AND DYNAMIC HARDNESS.

Fig. 5.

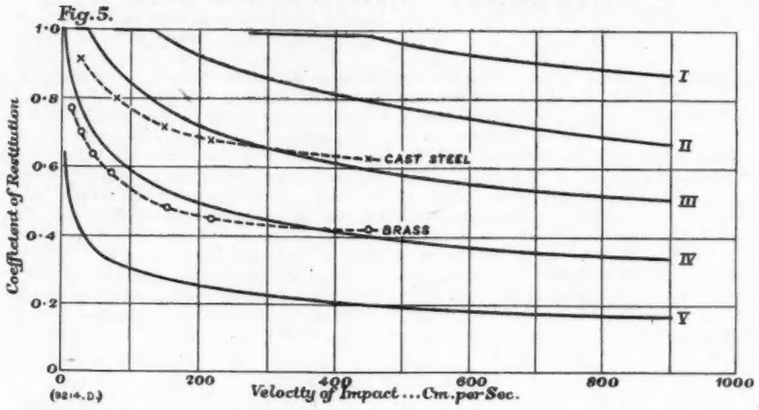
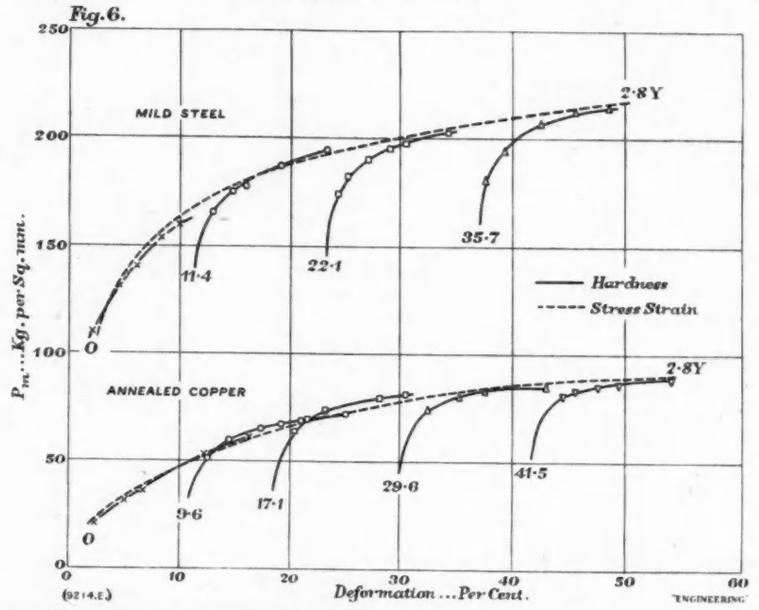


Fig. 6.



in the mean pressure resisting deformation. The order of this effect may be estimated by assuming, on analogy with the static case, that $P = k d^{n-2}$, where n is constant with a value between 2 and 2·5 (see equation (1)). If the above analysis is followed right through, a relation similar to equation (6) is obtained. The actual result is

$$P = \frac{n+2}{4}\frac{mg}{V_a}(h_1 - \beta h_2), \quad . \quad . \quad (6a)$$

where $\beta = \frac{2n-1}{2n+4}$ and therefore varies from $\frac{3}{8}$ to $\frac{4}{9}$ as n varies from 2 to 2·5. This has little effect on the value of P. Similarly, the first term varies from 1 to 1·12 as n varies from 2 to 2·5. It follows that the variation of the yield pressure as a result of work hardening during the process of indentation will at most cause an error in P, when equation (6) is used, of about 10 per cent. In general, the error will be appreciably less.

According to equation (5), if attention is restricted to any one material (for which P and E are assumed to be constant), the height of rebound h_2 should be proportional to a^5. This has been directly confirmed in a series of experiments by Edwards and Austin. Similarly, if impact experiments are carried out on a whole series of metals, the height of rebound h_2 for a fixed size of indentation (a = constant) should be proportional to $P^2\left(\frac{1}{E_1}+\frac{1}{E_2}\right)$. Results from the same authors are given in Fig. 3, page 289, where P has been calculated from equation (6). Using logarithmic ordinates and plotting $P\sqrt{\frac{1}{E_1}+\frac{1}{E_2}}$ against h_2 it is seen that over an extremely wide range of materials the points lie on a straight line of slope $\frac{1}{2}$.

Finally, a may be eliminated between equations (5) and (6). The resulting relation between h_1, h_2 and P is then given by

$$h_2 = K\left(h_1 - \frac{3}{8}h_2\right)^{\frac{3}{4}} P^{\frac{5}{4}}\left(\frac{1}{E_1}+\frac{1}{E_2}\right). \quad (7)$$

Since the bracket involving Young's moduli does not vary greatly for most metals, this factor may be treated as a constant and P plotted as a function of h_2 for a given height of fall h_1. The theoretical curve is shown in Fig. 4, page 289. To allow for the fact that softer metals usually have a smaller Young's modulus, the curve is modified in a manner similar to that shown in the dotted curve. These theoretical curves do, in fact, reproduce the main characteristics observed in the practical calibration of rebound scleroscopes. It is evident from Fig. 4 that, over a wide range of experimental conditions, the height of rebound, for a fixed height of fall, is almost directly proportional to the dynamic yield pressure.

It is interesting to consider what happens when $h_2 = h_1$, i.e., when the collision is completely elastic. Going back to the original equations, and calculating the maximum pressure P_e developed between surfaces colliding elastically,

$$P_e^{\frac{5}{2}} = \frac{1}{26}\frac{mgh_1}{r_1^3}\frac{1}{\left(\frac{1}{E_1}+\frac{1}{E_2}\right)^4}. \quad . \quad (8)$$

is obtained. This is precisely the value obtained if we put $h_1 = h_2$ in equation (7). Two conclusions follow from this result: firstly, that equation (7) is valid right up to 100 per cent. rebound, and secondly, if the yield pressure of the metal is greater than P_e, no plastic deformation occurs and the collision is completely elastic. If it is less than P_e, plastic deformation occurs and the value of P is the dynamic yield pressure of the material. This approach has been used by Taylor* to study the limiting conditions for plastic yielding under dynamic conditions. It is also evident that the rebound method will not discriminate between materials possessing yield stresses above P_e since they will all give a rebound of 100 per cent. To increase the range of the method the value of P_e must be increased either by increasing h_1 or m, or by reducing r.

If v_1 is the velocity of impact and v_2 the velocity of rebound, the ratio $\frac{v_2}{v_1}$ is the coefficient restitution e. We may calculate e from equation (7) by putting $v_1^2 = 2gh_1$; $v_2^2 = 2gh_2$. If we assume that P remains essentially constant, we obtain

$$v_2 = k\left(v_1^2 - \frac{3}{8}v_2^2\right)^{\frac{3}{8}}. \quad . \quad . \quad (9)$$

It is clear that v_2 depends on v_1, so that e will not be a constant. The way in which e varies with the velocity of impact is shown in Fig. 5, opposite, where curves (I, II, III, IV and V, respectively) have been drawn for values of e=1·0, 0·8, 0·6, 0·4 and 0·2 at an impact velocity of 450 cm. sec. (This corresponds to a height of fall of 100 cm.) Because P is not a constant there will be some deviation from these curves. Nevertheless, the general form of the curves is fully substantiated in practice. Typical results for cast steel and drawn brass are shown in the dotted lines and similar curves have been obtained by Raman, Okubo and Andrews in experiments on the impact of spheres of similar metals.

It is clear from equation (9) and from the experimental results that, in general, the coefficient of restitution of plastic solids will not be constant. At sufficiently low velocities of impact the collisions will be purely elastic and the coefficient of restitution will be unity. This occurs even with the softest metals, as Andrews showed in his experiments with spheres of lead and tin alloys. As the velocity of impact is increased, the amount of plastic deformation steadily increases and there is a corresponding decrease in the coefficient of restitution.

Some impact experiments were carried out on massive anvils of various metals using hard-steel balls. By measuring h_1, h_2 and d, the dynamic yield pressure P was calculated using equation (6). Some static experiments were also carried out and determinations made of the static yield pressure P_m required to produce impressions of the same diameter as in the corresponding impact experiments. The results showed two main points. Firstly, the dynamic yield pressure P was always greater than the static yield pressure P_m. This was particularly marked with the soft metals lead and indium. Secondly, the dynamic yield pressure increases, the greater the velocity of impact. This suggests that in calculating P from equation (6), i.e., from the energy required to produce an indentation of given volume, part of the energy is used in the dynamic displacement of the metal around the indentation. This view is confirmed by a calculation of the yield pressure from the height of rebound h_2. We do this using equation (5) and give P the suffix r (P_r) to show that it is calculated from the rebound height. The results show at once that although P_r is larger than P_m it is very much closer to the static value than in P, as may be seen from a few typical values in Table II.

TABLE II.—*Static and Dynamic Pressures.*

Metal.	$\frac{P}{P_m}$.	$\frac{P_r}{P_m}$
Steel	1·28	1·09
Brass	1·32	1·10
Aluminium alloy	1·36	1·10
Lead	1·58	1·11
Indium	5·0	1·6

Diameter of ball, 0·5 cm. Height of fall about 300 cm.

The fact that the dynamic yield pressure is higher than the static and increases with the velocity of impact suggests that, in the dynamic deformation of metals, forces of a quasi-viscous nature are involved. This is borne out by the results for the soft metals, lead and indium, where the pressures required to produce plastic deformation dynamically are very much greater than the static values. This cannot be due to the work-hardening which may occur rapidly during the formation of the indentation since at the end of the impact, where the work-hardening would be a maximum, the effective flow pressure P_r is very much smaller than the mean dynamic flow pressure P which is involved during the course of the impact itself. It would seem that in the deformation of soft metals, where relatively large volumes of metal are displaced, appreciable forces are called into play as a result of the "viscous" flow of the deformed material surrounding the indentation.

Finally, at the end of the impact process all plastic flow of the material has ended and there is no further bulk displacement of the metal around the indentation. All the deformation around the indenter is now of an elastic nature and any kinetic energy imparted to the material under these conditions is reversible. Consequently, the pressures involved in this portion of the collision process (P_r) are only a few per cent. higher than those involved in the formation of indentations of the same size under static conditions.

In the previous discussion we saw that the plastic deformation of a metal by a spherical indenter comes to an end precisely at the stage where the stresses come within the elastic limit of the material. We shall now describe a simple analysis which correlates the hardness of a metal with its elastic limit and with the way in which the elastic limit varies with the amount of deformation to which the metal has been subjected. We first make use of the theoretical result of Hencky, and more recently of Ishlinsky.* If a frictionless cylindrical or spherical punch is pressed on to the surface of an ideally plastic material the mean pressure P_m at which plastic yielding of the material just occurs is related to the yield stress or elastic limit Y of the material by a simple relation

$$P_m = c\,Y \quad . \quad . \quad . \quad (10)$$

where c has a value between 2·6 and 3. An ideally plastic material is one in which the elastic limit is constant and does not depend on the amount of deformation to which it has been subjected; that is, it does not work-harden. In practice, this is unattainable, but as a first approximation, we may use metals that have been very highly worked, so that they are incapable of appreciable further work hardening. Some typical results for hard spherical indenters are given in Table III, the elastic limit Y being found from careful compression experiments.

TABLE III.—*Results for Hard Spherical Indenters.*

Metal.	Y kg. per sq. mm.	P_m kg. per sq. mm.	Ratio $\frac{P_m}{Y}$
Tellurium lead ..	2·1	6·1	2·9
Copper	31	88	2·8
Mild steel	65	190	2·8

The value of P_m increased slightly with the size of the impression made, but it is clear that, to a first approximation, we may use equation (10) to correlate the yield pressure with the elastic limit.

If the metal is incapable of work hardening, the elastic limit Y is a constant and, as we have seen, equation (10) may be used. With most metals, however, as the spherical indenter sinks into the surface the elastic limit will increase. Although the elastic limit will not be constant at every point around the indentation, it may be expected that there exists an average or "representative" value of the elastic limit which is related to the mean pressure P_m by a relation of the same type as equation (10). Before describing a simple method of determining this "representative" value, the way in which the size of the indentation affects the deformation and work hardening of the metal may be considered in general terms.

Suppose the indentation has a diameter d and a radius of curvature r_2. Since it is a portion of a sphere its shape is completely defined by the dimensionless ratio $\frac{d}{r_2}$. Then for all indentations for which $\frac{d}{r_2}$ is the same, the amount of deformation or strain at the "representative" region will be the same if the grain size of the material is sufficiently small to be irrelevant. It may be said, therefore, that the strain produced at the representative region is simply a function of $\frac{d}{r_2}$. Since r_2 is usually very near the radius of the indenting sphere $\left(r_1 = \frac{D}{2}\right)$, the deformation becomes approximately equal to $\delta = f\left(\frac{D}{p}\right)$. This equation means simply that geometrically-similar indentations produce

* James Forrest Lecture, *Jl. Inst. C.E.*, vol. 26, page 486 (1946).

* *Jl. App. Math. & Mech.*, U.S.S.R., vol. 8, page 233 (1944).

similar strain distributions. Consequently we may expect the "representative" value of the elastic limit to be a simple function of $\frac{d}{D}$.

We may now consider a direct method of measuring the elastic limit of the material around the indentation. A convenient method of doing this is to determine the hardness of the material using a hard pyramidal indenter as in the Vickers test. In this case, since the indentation is geometrically similar whatever its size, the hardness is almost independent of the load. If therefore we measure the Vickers hardness of a metal that has been compressed or elongated by various amounts, a direct relation is obtained between the hardness number, the amount of deformation or strain and the elastic limit at any stage. This relation may then be used to determine the elastic limit of any specimen of the metal.

Relations of this type were determined for specimens of mild steel and annealed copper. Brinell impressions of various sizes were then made in the surface of specimens of these metals and Vickers hardness measurements made at small loads (to give very small impressions) in the free surface of the specimen. In this way the elastic limits of the deformed material in the free surface around the indentation and in the indentation were determined. These measurements show that the elastic limit of the metal gradually rises as the edge of the indentation is approached. At the edge itself the elastic limit rises rapidly and then falls somewhat as the centre of the indentation is approached. There is also a variation in hardness at various depths in the bulk of the material. Although it would appear difficult therefore to assign a "representative" value to the elastic limit of the whole material around the impression, empirical tests suggest that the elastic limit at the edge of the indentation may be used for this purpose. For example, by comparing the elastic limit Y_e at the edge of the indentation with the mean pressure P_m used in forming the indentation, it is found that, over a wide range of indentation sizes, $P_m = c\,Y_e$, where c has a value lying between 2·6 and 2·8. Further, the deformation corresponding to Y_e is approximately proportional to the ratio $\frac{d}{D}$, i.e., if the deformation is expressed as a percentage

$$\delta = 20\,\frac{d}{D}.$$

We may now compare the stress-strain characteristics with the hardness measurements. The results for mild steel and annealed copper are shown in the curves marked O in Fig. 6, on page 290. For the hardness curves, the values of P_m have been plotted against $\frac{d}{D}$, where the deformation is assumed to be equal to $20\,\frac{d}{D}$. For the stress-strain curve the elastic limit found in compression experiments has been multiplied by a constant factor and plotted against the deformation. There is close agreement between the two curves.

This analysis may be extended to hardness measurements on materials which have been deformed by various amounts. Measurements similar to those described above show that the "representative" deformation is approximately additive to the initial deformation δ_0, i.e., to a first approximation $\delta = \delta_0 + 20\,\frac{d}{D}$. Thus the hardness measurements give a series of $P_m - \frac{d}{D}$ curves that are displaced along the deformation axis by amounts equal to the initial deformation. Consequently the stress-strain curves correspond to the envelopes of the hardness curves (see Fig. 6).

Meyer's laws for unworked metals may be derived readily from these results. Over an appreciable range of deformtion, the elastic limit is a simple power function of the deformation or strain

$$\text{i.e., } Y = b\,\delta^x \quad . \quad . \quad . \quad (11)$$

where b and x are constants.

As has been shown, to a first approximation the deformation at the edge of the indentation, which gives the "representative" deformation, is directly proportional to $\frac{d}{D}$. We may, however, assume a more general relation and write

$$\delta = q\left(\frac{d}{D}\right)^y \quad . \quad . \quad . \quad (12)$$

where q and y are constants.

Hence the representative value of the elastic limit may be written as

$$Y = \alpha\left(\frac{d}{D}\right)^z$$

where $z = x\,y$ = constant and α = constant. Finally, since $P_m = c\,Y$ we have

$$P_m = \frac{4\,F}{\pi d^2} = c\alpha\left(\frac{d}{D}\right)^z$$

or

$$\frac{F}{d^2} = A\left(\frac{d}{D}\right)^z, \quad . \quad . \quad . \quad (13)$$

where A is a constant. If for convenience we write $n = z + 2$, this yields

$$F = \frac{A\,d^n}{D^{n-2}}. \quad . \quad . \quad . \quad (14)$$

Thus for indentations made with balls of various diameters D_1, D_2, D_3 . . .

$$F = k_1 d^n = k_2 d^n = k_3 d^n \quad . \quad (15)$$

where k_1, k_2, k_3 . . . are given by

$$A = k_1 D_1^{n-2} = k_2 D_2^{n-2} = k_3 D_3^{n-2} \quad (16)$$

The laws expressed by these equations were first deduced empirically by Meyer, and hold over a wide range of experimental conditions. Similar relations are also valid for metals which have been worked by various amounts.

It is interesting to note that the power y in equation (12) is found empirically to be nearly unity, so that $n = 2 + x$. This relation between the Meyer index (n) and the work-hardening index (x) appears to hold fairly closely, particularly for metals which have not been very highly worked.*

Similar considerations may be expected to apply in the case of pyramidal and conical indenters. For these indenters the indentations are geometrically similar whatever the size of the indentation. Consequently the "representative" deformation produced by the indentation and the "representative" value of the elastic limit will be constant. As a result, the mean pressure P_m required to produce plastic flow should be independent of the size of the indentation if the friction between the indenter and the metal is negligible. Experiments show that this is generally true.

In the Vickers hardness measurements, a shallow pyramidal indenter is used and the hardness number H is expressed as the ratio of the applied load to the superficial area of the indentation formed. From the geometry of the indentation it is found that $H = 0{\cdot}93P_m$. Empirical measurements similar to those described above suggest that the "representative" deformation δ produced by the indentation corresponds to a value of about 8 to 10 per cent., while the constant c connecting the mean pressure P_m with the "representative" value of the elastic limit Y lies between 3·2 and 3·4.† Consequently the Vickers hardness number is 2·9 to 3 times the "representative" value of the elastic limit of the material around the indentation.

Typical values obtained for the steel and copper specimens used in the earlier experiments are given in Table IV. Vickers hardness measurements were made on specimens of these metals after they had been deformed by various amounts δ_0. The elastic limit corresponding to a deformation of $(\delta_0 + 8)$ per cent. was then determined from the stress-strain curves of the metals. This value is assumed to correspond to the "representative" value of the elastic limit around the indentation. It is compared, in the table, with the observed Vickers hardness numbers.

* Dr. H. O'Neill, *Proc. I. Mech. E.*, vol. 151, page 114 (1944).

† This result may be compared with similar experiments by Bishop, Hill and Mott (*Proc. Phys. Soc.*, vol. 57, page 147 (1945) on the penetration of highly worked copper by hard steel cones. For a cone of the same semi-angle as the Vickers diamond they obtain a value of 3·4 for the ratio of P_m to Y.

The agreement is reasonably good over a wide range of deformations. It is also evident from the values of δ and c that the Vickers hardness numbers will be close to the Brinell hardness numbers over an appreciable range of hardness values.

This analysis is of an essentially crude nature but it does describe the main characteristics of hardness measurements and explains in a semi-quantitative way a number of well-established empirical relations. It is clear that hardness measurements are essentially a measure of the elastic limit of the material being examined. With pyramidal or conical indenters, where the indentation is geometrically similar whatever its size, the mean pressure to produce plastic flow is almost independent of the size of the indentation. Consequently, the hardness number has a single value over a wide range of loads. With spherical indenters, however, the amount of work-hardening and hence the elastic limit increases with the size of the indentation. As a result, the yield pressure in general increases with the load. Measurements with spherical indenters thus provide information firstly about the elastic limit of the material, and secondly about the way in which the elastic limit increases with the amount of deformation. This was first described empirically by Meyer in 1908, and the analysis given here shows that, to a first approximation, the work-hardening index x is related to the Meyer index n by the relation $x = n - 2$. In this way, a series of hardness measurements with a spherical indenter may be used to determine the degree of work-hardening of a given metal.

TABLE IV.—*Relation Between Elastic Limit and Vickers Hardness Number.*

Metal.	Initial Deformation, δ_0 per cent.	$\delta = (\delta_0 + 8)$ per cent.	Y at kg. per sq. mm.	c Y.	Observed Vickers Hardness Number.
				2·9 Y.	
Mild steel ..	0	8	55	159	156
	6	14	62	176	177
	10	18	66	190	187
	13	21	67	194	193
	25	33	73	211	209
				3·0 Y.	
Annealed copper	0	8	15	45	39
	6	14	20	60	58
	12·5	20·5	23·3	70	69
	17·5	25·5	25	75	76
	25	33	26·6	80	81

LITERATURE.

Modern Rubber Chemistry. By DR. HARRY BARRON. Second edition. Hutchinson's Scientific and Technical Publications, 47, Princes-gate, London, S.W.7. [Price 36*s.* net.]

DR. BARRON's second edition has been considerably enlarged and revised, and is a useful addition to the somewhat limited list of general technical books on india-rubber. The title is somewhat misleading, as the book covers the wider field of the historical, physical and technological aspects of the industry and of the compounding ingredients, rather than the more narrowly scientific side of rubber chemistry. It is written in straightforward language, and should appeal to students, rubber-works staff, and to those concerned with rubber products; and, being annotated with over 500 references, will show students the way to more profound reading. The user of rubber products will learn of the wide uses to which rubber can be applied, its special qualities and its peculiar limitations; and the younger man will find in it a useful summary of the developments of recent years. Wisely, we consider, the author omits the work done on synthetic rubbers.

Part 1 sketches briefly the history and sources of natural rubber, and Part 2 deals with its chemical and physical properties, adding, with reference to the structure of rubber, some useful material to that in the first edition. Part 3 reviews the processing of rubber in a rather elementary manner; some of the illustrations here are rather out of date. Part 4, on the scientific aspect of vulcanised rubber, brings the work up to date as far as possible. Part 5 is mostly new and deals with the generally accepted

technological methods of production. It describes briefly the processing departments, calendered sheet, extrusion, solution and proofing, and then gives a general idea of the production departments from moulded articles to tyres, hose, belting and rubber-to-metal developments. The author refers to the saving of time which results from the inclusion of appropriate compositions and mixes for specific products. Those whose job it is to produce such recipes will be wise to consider the examples only as very general guides to the usual type of compound used; it is being realised at last that a production specification which is effective in one rubber factory may not be suitable for use in another, as the variations in natural rubber, in its ingredients, and in the design of rubber machinery, considerably affect the resultant product. The book is provided with an excellent index, and is a distinct improvement on the first edition.

Fluid Mechanics. By PROFESSOR R. C. BINDER. Prentice-Hall, Incorporated, 70, Fifth-avenue, New York City, U.S.A., and Constable and Company, Limited, 10, Orange-street, London, W.C.2. [Price 30*s.* net.]

THE aim of this book, originally published in 1943, is to provide an introduction to the fundamentals of fluid mechanics. Evidently, the sequence of the subject matter has been carefully considered and is very satisfactory, but the field covered seems rather extensive for the relatively small size of the book. Basic principles are explained in the first six chapters. The explanation of the derivation of the Bernoulli equation is good, and proper emphasis is placed upon the importance of viscosity and the use of dynamical analysis and dynamical similarity in connection with fluid-motion problems. The author uses the "slug" ft.-sec. system and makes the statement that viscosity can be expressed in either lb. sec. per sq. ft. or slugs per ft. sec. It must be pointed out, however, that the slug per ft. sec. is not a logical unit for the measurement of viscosity and that its use should be discouraged. Applications of basic principles are given in a series of chapters which deal with flow of incompressible fluids in pipes, fluid-measuring instruments (introducing the use of the Venturi, orifice, weir and other methods), momentum problems, resistance of immersed bodies, dynamic lift and propulsion, dynamics of compressible flow, flow of compressible viscous fluids in pipes, and open-channel flow. The author includes a chapter explaining the principles of fluid lubrication.

Two chapters dealing with pumps and turbines are to a large extent descriptive and the reference to specific speed is hardly sufficient to explain properly the significance of this important criterion. The description of the construction and operation of the fluid coupling and torque converter is too brief to have much real value, and eight pages are inadequate for a proper description of fluid power and control systems. The utility of the mathematical study of fluid motion, in the final chapter, is also questionable. The book is well illustrated with line diagrams, but Fig. 54, illustrating the Johnson method for computing pipe flow, is too small and overcrowded with lines to be of practical use. There is much in the book to interest lecturers and it can be recommended to students studying under supervision. It is doubtful, however, whether it is altogether suitable for those who have not this advantage.

Plastics Manual. By H. R. FLECK. Published for Temple Press, Limited, Bowling Green-lane, London, E.C.1, by the English Universities Press, Limited, Saint Paul's House, Warwick-square, London, E.C.4. [Price 15*s.* net.]

THE properties of the formidable array of compounds now embraced within the scope of practice of the plastics industry constitute a serious tax on the memory, even of those who are intimately connected with the subject. Merely to know where the information is to be found is a considerable achievement, while the subsequent search for data among a miscellany of publications is a tedious and time-consuming task. Mr. Fleck's manual aims at relieving the plastics technologist of such work by providing in a single volume an orderly summary of factual knowledge, covering almost the entire commercial field of thermo-plastic and thermo-setting substances, including synthetic resins used in paint manufacture, cements and adhesives, densified wood products and fillers. Under each of a dozen parent types, the offspring substances are considered with respect to their chemical composition and mode of synthesis, their mechanical and other physical properties, and their appropriate applications and methods of fabrication into finished articles. The author has succeeded in localising practically all the information relating to each individual substance, thereby enhancing the merits of his text as a source of reference to readers interested mainly in using plastics as well as to those concerned with preparing and developing them.

In this, as in Mr. Fleck's previous books, the emphasis is on the chemistry of plastics and on the chemical aspects of manufacturing processes; and, while his concise surveys of mould design, mechanical methods of producing plastic goods, and ancillary operations like heating and laminating, are accurate and instructive, they give the impression of being included to benefit the plastics chemist for whom the manual is primarily intended. For this reason especially, it is unfortunate that some of the formulæ quoted in the section on mechanical testing are marred by lack of clarity and by errors which it is straining charity to describe as misprints. They will not, of course, mislead engineers, who are more likely to deplore the omission of a comprehensive list stating the chemical equivalents of the proprietary names under which the majority of plastic products are marketed. Lacking such information, the prospective user will admittedly find valuable guidance in the suggestions for identifying commercial plastics by their behaviour when burned or examined in ultra-violet light. Of this sort of testing, as well as in his recommended methods for the more elaborate analysis of raw plastic materials and fabricated products, the author writes with characteristic assurance. On the whole, the well-documented text, introduced by concise accounts of recent progress and raw materials, is an acceptable source of compactly presented information for all technologists who make or use plastics.

Alternating Current Electrical Engineering. By PHILIP KEMP, M.Sc.(Tech.), M.I.E.E., A.I.Mech.E. Seventh edition. Macmillan and Company, Limited, St. Martin's-street, London, W.C.2. [Price 25*s.* net.]

ALTERNATING-CURRENT electrical engineering has developed in many directions since this book first appeared in 1918, and its various editions have shown progressive changes in detail contents, the mercury-arc rectifier being an obvious example of an appliance which has become of great industrial importance since then. The present edition has been practically rewritten in order properly to co-ordinate the many modern advances. The subject of the volume is the principles underlying the design of electrical machinery, and although there are chapters on the design of transformers, alternators and induction motors, they are concerned with the application of principles and do not treat their subjects from the point of view of a drawing-office manual. A student passing from a technical college into industry learns the practical details of design in a works drawing office or design department, but he must have a proper grasp of the fundamentals of the applications with which he is concerned. It is the purpose of this book to give him the necessary mental equipment. It constitutes an admirable text-book for use in courses preparing for National Certificates and for college students studying for an engineering degree.

The book is concerned with electrical machinery and the extensive subject of thermionic valves is not dealt with except as far as is necessitated by proper treatment of the mercury-arc rectifier. With this omission, however, there is still a very large field for treatment, and in addition to chapters dealing with transformers, alternators, the various types of alternating-current motors, rotary converters, frequency changers, etc., there are others concerned with power factor, capacitance, resonance, iron losses and other phenomena common to many types of apparatus. As the book contains 659 pages and 450 diagrams and sketches, its price compares favourably with that of many text-books published at the present time.

THE ENGINEERING OUTLOOK.

XIII.—THE ELECTRIC CABLE INDUSTRY.

THE electric cable industry experienced a remarkably successful year during 1947, despite the fuel crisis, difficulties in securing adequate and regular supplies of materials, some shortage of operatives, rising costs, and many other problems common to almost every section of engineering. Available production statistics, compiled by the Ministry of Supply, are shown in Table I, herewith. The rate

TABLE I.—*Production of Insulated Electric Wires and Cables: Monthly Averages.* (£1,000).

	Total.	Home.	Export.	Retained Imports.
1935	1,646	1,422	224	20·0
1946	3,332	2,512	820	25·3
1947—1st Qr. ..	3,403	2,599	803	4·1
2nd Qr.	4,586	3,450	1,136	5·4
3rd Qr. ..	4,878	3,490	1,387	7·5

of production of insulated wires and cables has improved uninterruptedly during the year, the average monthly value of output rising from 3·33*l.* million during 1946 to 3·40*l.* million during the first quarter of 1947, 4·58*l.* million during the second quarter, and 4·88*l.* million during the third quarter. This compares with 1·64*l.* million during 1935, the most recent pre-war year for which statistics are available. Assuming a price increase of some 150 per cent. since that year, the volume of production during the third quarter of 1947 would appear to have exceeded the 1935 level by some 12 per cent. This is roughly corroborated by the fact that the labour employed increased by 8 per cent. during the same period, from 28,000 in 1935 to 30,200 in September, 1947. The estimated increase in the volume of production, however, may not fully reflect the extensions to capacity that have been made since the end of the war. Manufacturers' attempts to meet an unprecedented level of demand have been limited to some extent by the shortage of materials and components. The value of output is not expected greatly to exceed 5*l.* million per month (at current prices) in the foreseeable future, owing mainly to the impossibility of increasing the industry's supplies of lead, copper, jute and timber. This probably means that, during the current year, the rate at which orders are coming in will continue to exceed the rate of deliveries. Order books are now fuller than at any time in the history of the industry, representing, for the majority of companies, two to three years' work at the present high level of activity.

A description of the main problems that have confronted the industry during 1947 is found in the statements of the chairmen of companies at their annual general meetings. In certain cases, some indication is given also of how major problems are being tackled; for example, the shortage of certain important materials by the development of substitutes, the shortage of labour by increased mechanisation and incentive schemes, and rising costs by economies through increased standardisation, etc. Sir George Usher, chairman of Aberdare Cables, Limited, stated in March: "Our most serious problem at the moment is in maintaining a steady flow of raw materials to the factories. There is a world-wide shortage of two of our principal raw materials—lead and copper. Both are subject to Government control and licence. Other raw materials, such as jute and timber, are difficult to obtain. The prices of these, as of copper and lead, are continually rising; in fact, there is no stability in the prices of any of the raw materials used by your company, a problem which adds greatly to the difficulties of management."

Mr. G. Leslie Wates, chairman and joint managing director of Johnson and Phillips, Limited, speaking in May, stated that his company's order book was fuller than it had ever been, but complained that shortages of materials and labour prevented any acceleration of output "to keep pace with the increasing volume of business being offered to us . . . one might even say being thrust upon us"; with

the result that many orders could not be completed for two years or more, and that further orders could only be accepted "subject to many reservations which are very unwelcome to our customers." Mr. Wates warned his shareholders that they must not expect the seller's market to last for ever. "The demand for electrical products certainly seems almost limitless at the moment," he said, "but we must envisage the time when Central Europe will again be producing and when the great industries of the U.S.A. will have overtaken their home demand. By that time it will be a matter of life and death for our industries to have brought their manufacturing technique to the highest level of efficiency so that our costs will compare satisfactorily with those ruling in other parts of the world."

This concern about costs is doubtless prompted by the fact that the prices of copper and lead are now 100 and 200 per cent., respectively, above the mid-1946 level. The British home price for electrolytic copper was raised by 19*l.* to 117*l.* a ton at the beginning of 1947, and it moved with the world price, rising to 127*l.* in February and 137*l.* in March. It was maintained at this level until July, when it was reduced to 132*l.* The British price was substantially higher than the New York price throughout the year; in December, the latter stood at 21¼ cents per lb. (121*l.* a ton). It is unlikely that supplies will improve in the immediate future, although world production in 1947 is estimated at about 2 million tons, compared with 1·7 million tons in 1946. Active demand continues because of the high level of industrial activity throughout the world, especially in the United States, where the Government have commenced purchases for strategic "stockpiling." There was a substantial improvement in world lead production, which is estimated at 1·3 million tons in 1947, compared with 987,000 tons in 1946, but production still lags far behind the pre-war level (1·65 million tons in 1938); moreover, all major sources of supply, except Australia, are dollar areas. The New York export price, at 15 cents per lb. (83*l.* a ton), was over three times its pre-war level. The British price of lead rose from 55*l.* to 71*l.* 10*s.* a ton in February and again to 90*l.* a ton in March and remained at this level until the end of the year. Consumption in the United Kingdom continued to be severely restricted, totalling only 200,000 tons in 1947 compared with 324,000 tons in 1938. There is certainly nothing to suggest an improved supply of either metal during the coming months, and it is possible that lead supplies may be further restricted if Britain's dollar bankruptcy is not resolved. Stocks at the end of the year amounted to 40,000 tons, equivalent to only 2½ months' supply at the current rate of consumption. Fortunately, however, British prices, though higher than American, have moved with world prices, and during 1947 the export prices of cables were said to be competitive with those of foreign manufacturers, both in Europe and in the United States.

Sir Alexander Roger, chairman of British Insulated Callender's Cables, Limited, speaking at the annual general meeting of his company on June 2, complained of "an unprecedented shortage and irregular flow of raw materials and component parts" which, he stated, had an adverse effect on the management's ability to plan production and on the operatives' will to work and enthusiasm. His comment on future demand contained an urgent note of warning. Sir Alexander talked of a "fast receding buyers' market," saying that "buyers are increasingly dissatisfied with quotations being subject to costs of material and wages at the time of delivery, which may be one year or two years ahead." Steps taken by his company to overcome their difficulties included the extension of incentive schemes, the training of labour within industry, the review of manufacturing processes with the object of greater mechanisation, and the search for alternative materials, as well as the re-organisation of existing factories and "expansion schemes of some magnitude." Details of expansion schemes carried out by the industry since the end of the war are given in Table II, herewith. In March, it was announced that British Insulated Callender's Cables, Limited, had acquired a new factory at Melling, near Liverpool, to provide immediate additional facilities for the production of telecommunication equipment. This purchase was made necessary because of serious delays in the building of the company's new factory on the Kirkby Trading Estate of the Liverpool Corporation, which is not now expected to be completed for some two to three years.

The general labour situation improved during 1947. The number employed on the manufacture of insulated electric wires and cables rose from 27,100 at the end of 1946 to 30,200 at the end of September, 1947. This does not, of course, represent the total labour of all the firms in the industry, most of whom also manufacture other products. British Insulated Callender's Cables, Limited, for example, employ 40,000 people, of whom probably less than half are engaged on the manufacture of wires and cables. In November, it was announced that the National Joint Industrial Council for the Electrical Cable Making Industry had come to an agreement with regard to wages in order to meet the conditions created by the alteration of working hours to reduce electricity demand.

Table II.—*Electric Wires and Cables: Additions to Capacity Between January, 1945, and May, 1947.*

Company.	Location.	Area in Sq. Ft.	Estimated Labour Required.
Standard Telephone and Cables, Limited	Newport ..	201,000	1,000
			2,000
Rists Wires and Cables, Limited	Newcastle-under-Lyme	394,270	2,000
Scottish Cables, Limited	Renfrew.. ..	57,500	—
Pyrotenax, Limited ..	Hebburn, Co. Durham	90,000	500
Reliance Cords and Cables, Limited	Leyton, Essex ..	12,500	No addition
Kent Brothers Electric Wire Company and E. H. Phillips, Limited	Richmond, Surrey	10,350	150
Southern United Telephone Cables, Limited	Dagenham, Essex	13,025	390
British Insulated Callender's Cables, Limited	London	11,800	250
do. do.	Kirkby Trading Estate, Liverpool	23 acre site	—
W. T. Henley's Telegraph Company, Limited	Birtley, Co. Durham	403,200	1,050

Management labour relations appear to have been satisfactory throughout the year. British Insulated Callender's Cables report two special agreements negotiated through the recognised machinery. One provides for the continuance of the "guaranteed week" introduced during the war, though it is stated that this will not operate if the company are unable to provide work through circumstances beyond their control. Under the second agreement, the company accepted the principle of a shorter working week without any change in the normal weekly wage conditional upon the observance by the unions, and by all concerned, of their undertaking to co-operate effectively in measures for the maintenance of output. The General Cable Manufacturing Company, Limited, reported in January "considerable additional output obtained in approximately the same number of man-hours as in the previous year."

The technical achievement of the year was the successful laying in November of a new Anglo-Dutch submarine telephone cable between Aldeburgh in Suffolk and Domburg in Walcheren, in Holland. The new cable is a co-axial type and will enable 84 conversations to be conducted simultaneously without the aid of submerged repeaters. The manufacturers, Submarine Cables, Limited, are owned jointly by Siemens Brothers and Company, Limited, and the Telegraph Construction and Maintenance Company, Limited. The laying of this cable, which is now in public service, was the culmination of many years of research work. Another development of considerable importance in cablemaking was demonstrated by British Insulated Callender's Cables, Limited, in Edinburgh, London, Birmingham, Liverpool and Leeds. This is an impregnated high-voltage cable which was produced as a result of research commenced in 1928, culminating in the supply and laying at Burford of a three-core 132-kV cable for the Central Electricity Board. This was required when it became necessary to clear the approach to a war-time aerodrome, involving the placing underground of a mile of the 132-kV grid on the route from Oxford to Gloucester. The success of this prototype gives promise of important developments in the field of electrical power transmission, and it is likely to be widely used in built-up areas in place of overhead lines.

A war-time development which is likely to have wide applications is poly-ethylene, a long-chain paraffinic hydrocarbon with outstanding dielectric properties. This product was developed in Britain during the war, when the shortage of natural rubber caused manufacturers to concentrate on available substitutes. It made an important contribution to the high performance of radar equipment, and is of great value as a dielectric for high-frequency cables. Considerable research and development activities were reported by manufacturing concerns. A new research laboratory has been established jointly by the Automatic Telephone and Electric Company, Limited, and British Insulated Callender's Cables, Limited, at Taplow Court, for work on telecommunication equipment and apparatus, a field in which British industry has been largely dependent hitherto on overseas initiative.

The question of standardisation of power cables was discussed at a meeting of the Transmission Section of the Institution of Electrical Engineers in November. A paper advocating a considerable reduction in the number of alternative cables now available was read by Mr. W. H. Lythgoe, of W. T. Henley's Telegraph Works Company, Limited. He considered that the present multiplicity of standard types was not technically justified, and was conducive to high production costs. Unless some action were taken without delay by the industry as a whole, and manufacturing costs reduced to the minimum consistent with the maintenance of quality, Mr. Lythgoe considered that attempts to increase exports were likely to be defeated. This alone, quite apart from the advantages that would accrue at home, would, in his opinion, justify a detailed and thorough survey of the present position. The author's analysis showed that the number of different standard types which a manufacturer might be called upon to produce was of the order of 15,000 to 18,000, not counting those of "special construction" and certain others—for instance, 33-kV types—not yet included in the industry's standard ranges. Specific suggestions included the standardisation of a primary range of selected types and sizes in considerable demand, with a secondary list of others popular enough for addition to the primary range, but not in sufficient demand for inclusion in it. Manufacturers' stocks would thus be simplified, delivery improved, and production costs lowered if cable could be made in longer lengths than is now possible. Makers' records showed that the average order for power cable was for little more than a quarter mile in length.

The discussion that followed corroborated the author's assertion that ample scope existed for the introduction of some degree of standardisation, although speakers stated most of the usual arguments against too rapid an introduction of standard types: standardisation should not take place until experience had led almost to a common practice among users; it was essential to consider current practice and developments abroad if British cablemakers were to compete in foreign markets; differences in equipment and manufacturing methods in the industry; the fact that competition in the cable industry was keen, and that any general standardisation of cables would tend to limit competition, etc. It was also stated that, since the labour cost in cablemaking was only about 15 per cent. of total costs, any saving in cablemakers' labour costs would not materially affect the overall cost. These considerations once more restate the major problem facing the advocates of standardisation in any industry made up of competing units—how is it to be enforced if it does not arise from the nature of the demand, and, if it is enforced, how is the industry to continue on a competitive basis? Standardisation is far more likely to follow the formation of consumer monopolies, such as the nationalised electricity undertakings, the coal mining industry, etc., but even then it is likely to be a gradual process. The question of costs is

doubtless a major problem which the cablemaking industry will have to face in the fairly near future if it is to increase the proportion of its products sold in overseas countries. In this respect, it should be emphasised that pleasing the customer—that is, incorporating his detailed specifications in the product—is unlikely to be less important than formerly. The ideal solution, of course, is to increase the total volume of sales to such an extent that, as in the case of American manufacturers, the mileage of each type of cable produced is adequate for economic production without having to force upon customers any particular standard types.

Exports of insulated wires and cables totalled 13·2*l.* million during 1947, compared with 10*l.* million during the previous year and 4·1*l.* million in 1938. The average monthly value of exports during 1947 amounted to 1·1*l.* million, compared with 900,000*l.* during the last quarter of 1946. The industry should find little immediate difficulty in attaining its target during the current year (900,000*l.* per month), although rising costs and renewed competition from European and American manufacturers may render sales more difficult. Details of the destinations of exports are given in Table III, herewith, which is taken from the *Trade and Navigation Returns* for December, 1947. Nearly 62 per cent. of the total went to British countries, the best market being the Union of South Africa, with 2·28*l.* million, followed by British India, with 1·95*l.* million. The best foreign market was Argentina with 664,000*l.*

Since the end of the war, British cablemakers have been very active in setting up manufacturing facilities in their best overseas markets. There are now cable factories in all of the Dominions, and most of them are owned and run by British companies, except in Canada, where the industry is largely run by United States companies. British Insulated Callender's Cables, Limited, who are said to account for about 70 per cent. of the total British insulated wire and cable production, own factories in Australia and India, and are said to be acquiring manufacturing facilities in New Zealand. They also own a factory in China, but this is frequently idle because of political troubles. The Australian factory is at Liverpool, New South Wales; the Indian factory, at Tatanagar; and the New Zealand factory will be at Christchurch. W. T. Henley's Telegraph Works Company, Limited, own a factory at Vereeniging in South Africa. Johnson and Phillips, Limited, are developing local manufacture in South Africa and Australia to meet local conditions in certain ranges of products. In 1944, they acquired Godfrey (Proprietary), Limited, in Australia. The same company also state that there exists considerable scope for development work in India, but that the difficulty in recruiting the trained engineers required to carry out the contract work is retarding progress. The details given above relate to companies who are members of the Cable Manufacturers' Association, who are reputed to have an extremely efficient sales organisation, carrying out some measure of co-operative selling. This also operates where the cables are manufactured locally by the associated company of one of the members, part of the factory's output being sold under the trade mark of any of the other C.M.A. companies according to an agreed quota.

There are also independent companies with factories in the Dominions. Aberdare Cables, Limited, one of the largest companies outside the C.M.A., registered an associated company in South Africa (Aberdare Cables of South Africa, Limited) in August, 1946, with a capital of 400,000*l.* A factory is being erected at Port Elizabeth, where cables and certain electric specialities similar to those made by the company's British subsidiary, South Wales Switchgear, Limited, will be manufactured. In October, 1947, Aberdare Cables formed a new company in Eire, the Aberdare Electric Company, also with an authorised capital of 400,000*l.* Other independent companies with works in the Dominions include Rhodesian Cables, Limited, incorporated in Southern Rhodesia, who run a factory at Pretoria, South Africa, and are having two new factories erected—one at Salisbury and the other at Pietermaritzburg—for the manufacture of all types of rubber- and paper-insulated cables for lighting and power purposes up to 11,000 volts. Rhodesian Cables is run by Siverts, one of the principal Swedish companies. There is also an independent company in Australia, the Olympic Company, which is said to have started the manufacture of vulcanised india-rubber cables early in 1940. The nucleus of a domestic wire and cable industry was also started in India during the war. In the autumn of 1944, a new rolling mill was opened near Calcutta, belonging to the National Rolling Mills, Limited. This will produce copper rods for a sister company, the National Insulated Cable Company of India, Limited, who already have works in the Central Provinces and will be starting shortly a new factory near the rolling mills. Both concerns are under the management of Associated Industrial Developments Company, Limited.

Competition for overseas markets before the war came mainly from Germany, Italy and the United States. The value of the wire and cable exports of the principal manufacturing countries are shown in Table IV, herewith. Italy is not included, as exports of electric insulated wire and cable are not clearly distinguished in the Italian trade returns; but Italian exports before the war are known to have been substantial. The leading manufacturers, Pirelli, own almost all the Latin-American wire and cable manufacturing companies. From the Board of Trade figures shown in Table IV, it will be seen that, in 1938, Britain was the leading exporter, with 4·3*l.* million, accounting for 44 per cent. of the total; followed by Germany with 3·6*l.* million and the United States with 1*l.* million. During the war, the total value of exports increased rapidly from 10·2*l.* million in 1939 to 26·4*l.* million in 1943, when the peak was reached. In that year, the United States accounted for 55·8 per cent. of the total, followed by Germany with 29·5 per cent. and Britain with 13·9 per cent. American exports, which included Lend-Lease shipments, rose further in 1944, but had declined to 4·9*l.* million in 1946, when Britain accounted for 66 per cent. of the total.

Competition during the current year is likely to come from Italy as soon as the industry there is able to obtain the necessary raw materials; from the United States, as soon as the heavy home demand has been overtaken; and probably from Czechoslovakia. The American wire and cable industry is not large, but its output of wire and cable is exceeded by the aggregate output of other industries manufacturing wires and cables as products outside their normal range. In 1939, the industry comprised 79 establishments employing 15,696 wage earners, with a total output of 120·3 million dols. during the year, of which 90·1 million dols. represented wires and cables, 30 million dols. other electrical products such as telephone apparatus, washing machines, switches, switch boxes, wiring devices, etc., and the remainder, other non-electrical products and receipts for contract and repair work. The total value of wires and cables manufactured during 1939, however, amounted to 204·4 million dols., of which 114·3 million dols. was made in industries other than the wire and cable industry. Assuming the productivity of labour engaged on the manufacture of insulated wires and cables within and outside the American wire and cable industry to be the same, the production figures for 1939 suggest that about 35,600 were employed on this work, compared with 28,000 in Britain in 1935. The gross value of output per man employed in the United States, however, was about 5,750 dols. (1,300*l.*) compared with 610*l.* in the British industry in 1935. These are broad estimates, but they suggest a much greater use of mass-production methods in the United States than in Britain.

The German industry suffered considerable war damage, and at present lacks raw materials and fuel. Reports published since the end of the war by the British Intelligence Service Sub-Committee show that investigating teams of British technicians found that, although German cablemakers generally lagged behind British makers on the production and technical sides, they had met with marked success in the development of synthetic materials suitable for cable dielectrics; the B.I.O.S. Final Report No. 1190 states that "their results in this respect are probably in advance of our knowledge." It was also found that German builders had shown considerable ingenuity in the design and application of components of electric cables other than insulation materials and conductors. Examples quoted were the use of a steel sheath instead of lead, and staple fibre for cotton. The report concludes that, as these substitutes were cheaper and appeared to have certain advantages over the originals, "the possible results which could accrue from such developments in trade competition might be worth considering." It is difficult to assess how far the German wire and cable industry will be able to compete in world markets during the next few years. It is probable, however, that a large number of important factories which have been damaged could be made ready for full production in a few months if materials and labour were available.

Other competitors—Sweden, France and Switzerland—have well-developed industries with only a relatively small export margin. Czechoslovakia may become an important competitor, but is more likely to concentrate on Eastern European markets and Russia. It was announced in November that the Czechs are to supply Russia with large quantities of cables under the terms of a trade agreement negotiated in Moscow. The deliveries cover the whole of this year, and it was stated that shipments over a further four years were discussed. Russia will supply the necessary raw materials. In general, the British industry is considered to have a good opportunity to secure larger markets than before the war, but the question of price will tend to become more and more important during the coming months.

TABLE III.—*United Kingdom Exports of Wires and Cables by Countries* (£1,000).

Country.	1938.	1946.	1947.
Union of South Africa	828	1,479	2,282
British India	632	1,221	1,952
Australia	944	603	601
New Zealand	301	652	1,009
Other British Countries ..	652	1,501	2,325
Argentine Republic* ..	125	426	664
Sweden†	‡	125	455
Foreign Countries	629	4,003	3,954
Total	4,111	10,010	13,242

* Not including rubber-insulated cables.
† Only cables with insulation other than rubber.
‡ Less than £1,000.

TABLE IV.—INTERNATIONAL EXPORTS OF ELECTRIC WIRES AND CABLES, 1938-1946 (£1,000).

——	1938.	Per Cent.	1939.	Per Cent.	1940.	Per Cent.	1941.	Per Cent.	1942.	Per Cent.	1943.	Per Cent.	1944.	Per Cent.	1945.	Per Cent.	1946.	Per Cent.
United Kingdom ..	4,319	44·2	3,824	37·4	5,209	44·9	3,855	36·4	3,351	22·0	3,678	13·9	3,968	16·6	4,390	33·3	10,755	66·0
United States ..	1,009	10·2	1,252	12·2	4,956	42·6	4,893	46·3	10,114	66·4	14,731*	55·8	19,914*	83·3	8,675*	65·6	4,983	30·6
Switzerland	115	1·2	109	1·1	156	1·3	15	0·1	10	—	3	—	7	} 0·1 {	5	—	134	0·8
France	480	4·9	1,647	16·0	243	2·1	343	3·2	77	0·5	179	0·7	13		120	0·9	222	1·4
Sweden	287	2·9	256	2·6	156	1·3	134	1·3	37	0·2	37	0·1	6		24	0·2	203	1·2
Germany	3,567	36·6	3,137	30·7	905	7·8	1,343	12·7	1,667	10·9	7,791	29·5	—	—	—	—	—	—
Total	9,777	100·0	10,225	100·0	11,625	100·0	10,583	100·0	15,256	100·0	26,419	100·0	23,908	100·0	13,214	100·0	16,297	100·0

* Including Lend-Lease exports.

APPLICATIONS OF POWER CARTRIDGES.

THE use of cartridges as a source of power has been envisaged for many years, and during the latter part of the Nineteenth Century several attempts were made to adapt them for driving machines. No practical results were obtained, however, until the end of the 1914-18 war, when Messrs. Kynoch developed a cartridge for operating the humane cattle killer. The development of power cartridges, however, was accelerated appreciably during the recent war, when they were used for starting aircraft engines, cutting balloon-barrage cables, and for lowering aircraft undercarriages in an emergency. The last named application was used extensively on the Bristol Beaufort aircraft which employed a hydraulically-operated undercarriage arranged so that if the hydraulic system failed, a cartridge was fired and the gases used to operate the undercarriage jack. The cartridge employed contained 73 grammes of wrapped Meehanite charge and developed a pressure of from 1,000 lb. to 1,200 lb. per square inch. For cutting balloon cables, the leading edge of an aircraft wing was fitted with a framework arranged to form a series of angles, the apex of each angle pointing forward. When a balloon cable was encountered, it was directed by the framework into one of a number of points along the wing fitted with cutting mechanisms. These consisted of cartridge-operated chisels and anvils, and as soon as the cable entered a cutting location, the cartridge was fired automatically and the cable severed.

The most important of these developments, however, was the application of cartridges to the starting of aircraft engines, this method having been adapted subsequently to a wide range of industrial-type internal-combustion engines. In this application, the cartridges are used in conjunction with the Coffman starter originally developed in the United States and now manufactured by the Plessey Company, Limited, Ilford, Essex. This type of starter is useful for starting compression-ignition engines that come between the small hand-starting types and the larger types which employ compressed air for starting. It is particularly suitable for starting the smaller types of marine engines, such as those fitted in lifeboats, where the maintenance of heavy-duty batteries is undesirable. Fig. 1, on this page, shows a small marine-type petrol engine developing approximately 25 brake horse-power fitted with a Plessey starter.

The Coffman starter can be described as a mechanism whereby the horizontal movement of a piston is converted into rotational motion of a dog clutch fitted to the end of the engine crankshaft. The starter is in two parts, namely, a breech mechanism and the piston assembly. The breech mechanism may be likened to that fitted to a revolver, the power cartridges taking the place of the ammunition while the barrel is replaced by a steel pipe which leads the products of combustion to the cylinder assembly. The breech holds six cartridges and the cartridges may be fired either electrically or by percussion. In Fig. 1, the breech is shown fitted in the vertical position just above the starter. The piston assembly is shown diagramatically in Fig. 2, which is a longitudinal section through the centre line of the starter and will serve to illustrate its method of working. The gases from the cartridge enter the cylinder by the pipe *a* and act against the piston *b*. This causes the piston to move to the left, as drawn in Fig. 2, and it carries with it the hollow piston rod *c* which is held to the piston by the Circlip *d*. The piston rod *c* has helical splines machined in its external surface, which engage the internally-splined sleeve *e*, so that, as the piston advances, the action of the splines imparts rotary motion to the piston rod. The piston rod also has helical splines machined in its bore and these engage splines machined in the external surface of the shaft *f*; these splines, however, are of the opposite hand to those machined in the surface of the piston rod. Integral with the shaft *f* is the dog *g*, and the starter is located so that when it is inoperative, this dog is opposite, but not in engagement with, a mating dog fitted to the end of the engine crankshaft. It will be appreciated that the shaft *f* will not rotate in relation to the piston rod *c* but will be advanced bodily to the left until some form of resistance is offered to this travel, and use is made of this to bring the dogs into engagement. It will be seen in Fig. 2 that integral with the dog *g* is a sleeve on which is formed a thrust ring *h*, and that there is clearance between this thrust ring and the ball-thrust bearing *i*. When the piston advances, the shaft *f* will move bodily to the left and will not rotate in relation to the piston rod until the thrust ring *h* makes contact with the thrust bearing *i*, by which time the dogs are in engagement. When the piston reaches the limit of its travel, it makes contact with the spring *j* and pulls the rod *k* to the left, thus lifting the exhaust valve *l* from its seat and allowing the products of combustion to escape to atmosphere. The piston is returned by the helical spring *m*, but before it reaches the end of the return stroke, the small spring *n* makes contact with the base of the valve spindle and closes the exhaust valve, the sleeve *o* being integral with the piston. During the working stroke, the exhaust valve is held to its seat by the pressure of the gases and it is held open during the return stroke of the piston by a ball-detent fitted to the body of the valve. The exhaust valve and its guide are held in position by the plate *p*, which is drilled with a number of holes so as to permit the gas to pass.

Two sizes of starter are available, the L type and the S type. The L type develops a torque of 4,000 lb.-ft. and will rotate the clutch through an angle of 320 deg. The S type, however, is manufactured with three different angles for the splines, which give rotations of 400 deg., 500 deg. and 600 deg., the maximum torque being 650 lb.-ft., 550 lb.-ft. and 450 lb.-ft., respectively.

It is not always necessary to employ an external mechanism for starting engines by cartridges, as in some cases it is possible to use the method known as direct injection, in which the gases generated by the cartridge are led directly into one of the combustion spaces of the engine. This form of starting is a standard fitting on the Field-Marshall agricultural tractor which is manufactured by Messrs. John Fowler and Company (Leeds), Limited. This tractor is fitted with a horizontal single-cylinder two-stroke Diesel engine having a bore and stroke of 6½ in. and 9 in. respectively, and developing approximately 20 brake horse-power. The power cartridge used in this application has a 12-bore shotgun case and contains a priming charge of black-powder which is held in position and separated from the main cordite charge by a celluloid cup. The cartridge is fired by percussion and the gases are led into the cylinder head through the compression-release valve, the piston, of course, having been set previously at just over the top dead centre.

Cartridges are now being used to actuate water-drenching systems over processes involving the risk of sudden fire. This application was developed by Messrs. Imperial Chemical Industries, Limited, Nobel House, Buckingham Gate, London, S.W.1, during the recent war, and is being used in their explosives factories on cordite-processing rolls where it is essential that fires should be extinguished immediately. The system adopted involves the use of a photo-electric cell which detects the first sign of flame; the current produced is amplified and fires a small cartridge which, in turn, lifts a 9-in. diameter water-release valve, and the incipient fire is extinguished within a quarter of a second from the initial flash.

The above description gives only a brief outline of some of the many applications for power cartridges. In addition to those mentioned, power cartridges have been adapted to such varied applications as the re-cocking of powerful springs, the operation of portable fire extinguishers, and as the actuating force in a submersible bolt-driving machine, an illustrated description of which was given in ENGINEERING, vol. 162, page 597 (1946). In each case, the cartridges have been developed by Messrs. Imperial Chemical Industries, Limited, who are engaged continuously in the development of new propellants to meet the varying needs of industry. A recent innovation which, perhaps, exemplifies the wide field covered by these developments is the introduction of a gas-generating unit for driving model motor cars, aircraft and boats by jet reaction. The possible applications for power cartridges, therefore, are numerous; their use may provide the solution to problems associated with the starting of gas-turbine engines. Already a combined Coffman starter and epicyclic step-up gearbox has been used successfully for starting certain turbine engines, and it is understood that the British Thomson-Houston Company, Limited, have developed a cartridge-operated turbo starter for aircraft engines.

COFFMAN CARTRIDGE ENGINE STARTER.

THE PLESSEY COMPANY, LIMITED, ILFORD.

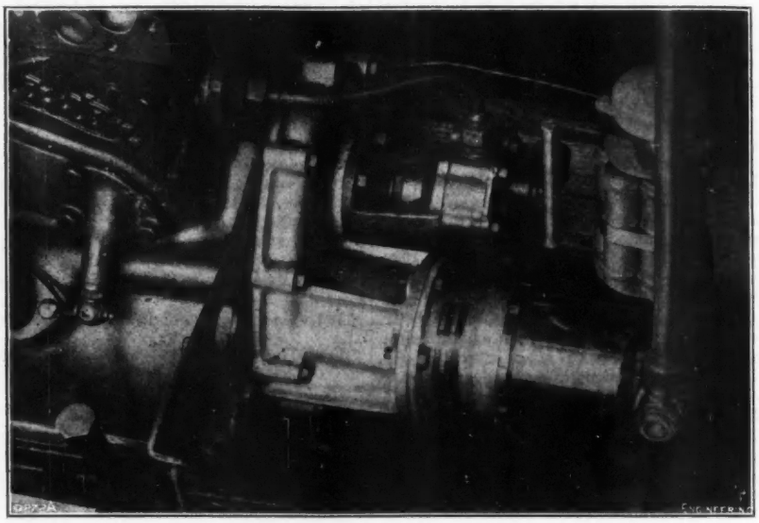
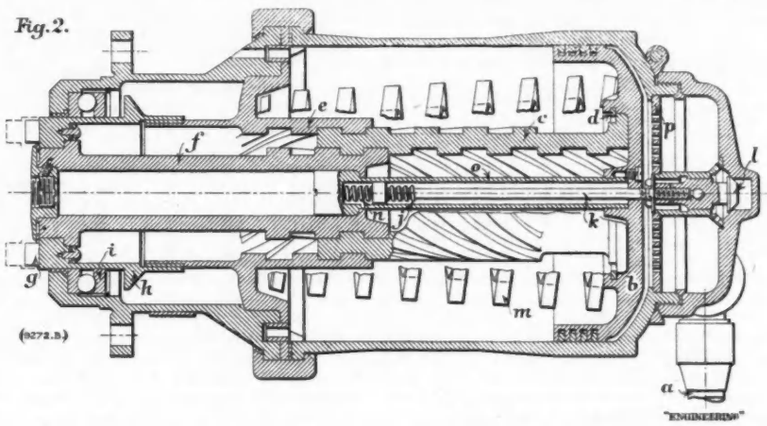


FIG. 1. STARTER FITTED TO 25-H.P. MARINE ENGINE.

Fig. 2.



CIVIL TRANSPORT AIRCRAFT.

THE BRISTOL AEROPLANE COMPANY, LIMITED, FILTON.

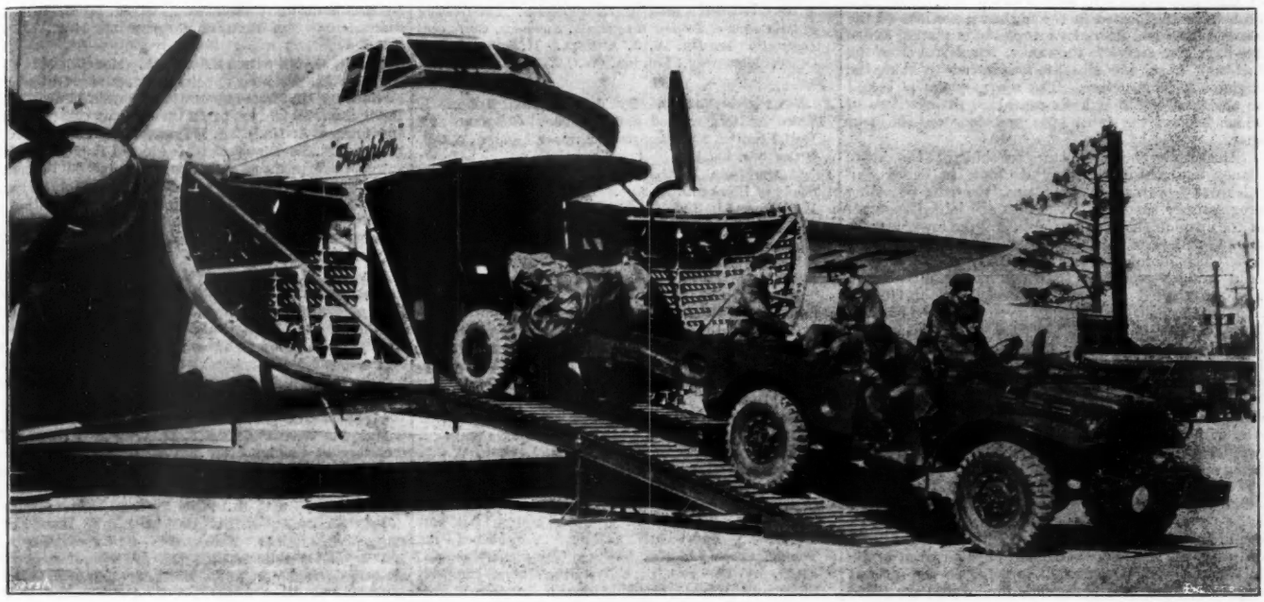


FIG. 1. AIRCRAFT FITTED WITH DOORS IN NOSE.

BRISTOL CIVIL TRANSPORT AIRCRAFT.

THE Bristol Aeroplane Company, Limited, Filton House, Bristol, have recently introduced an improved form of their Type 170 transport aircraft. Originally, this aircraft was granted a Certificate of Airworthiness at an all-up weight of 36,500 lb., but as a result of experience gained in operation in many parts of the world, the company formed the opinion that the aircraft was capable of operating at a considerably greater all-up weight than that permitted. As a consequence, they undertook an intensive flight-research programme in order to effect an improvement and the new form of the Type 170 has now been granted a Certificate of Airworthiness at an all-up weight of 40,000 lb. This latest aircraft has been designated the New Type 170, and is illustrated in Figs. 2 and 3, on page 300, from which it will be seen that, in appearance, there is little to distinguish it from its predecessor.

The development of the New Type 170 really commenced with a demonstration tour to the Americas in August, 1946, during which the aircraft showed itself capable of carrying a considerably greater payload than that permitted by its Certificate of Airworthiness. As a result of this tour, and others which followed, the Bristol Aeroplane Company collated a great deal of technical information which, supplemented by reports from operators in various parts of the world, gave a sound groundwork on which to base the work of development. From the commencement of flight testing and research analysis, it was appreciated that any increase in all-up weight must be subordinated to the need for maintaining a basic minimum rate of climb with one engine inoperative and subsequent tests, therefore, were based entirely on single-engine performance. The performance of the original prototype aircraft under this condition was 185 ft. per minute at an all-up weight of 36,500 lb. and this was considered to give a satisfactory safety margin. Increase of load, however, reduces this margin by approximately 23 ft. per minute for every additional 1,000 lb.; therefore, if single-engine performance could be improved by reducing drag, the all-up weight could be increased by 1,000 lb. for every 23 ft. per minute so gained.

Accordingly, in May, 1947, a production aircraft in prototype condition was allocated for experimental flying and initial tests resulted in the Air Registration Board granting a Certificate of Airworthiness at 37,000 lb. all-up weight. In view of the known capabilities of the aircraft, this increase was considered insufficient, and it was decided to investigate the possibilities of reducing drag and increasing the thrust horsepower by any means which avoided undue interference with production. The first step was to increase the span by 10 ft., an alteration that was not so drastic as it would appear owing to the original wing design incorporating detachable wing tips, chiefly for ease of replacement in case of damage. It was possible, therefore, to increase the span the required amount by substituting larger area wing tips, and by increasing the span from the then existing 98 ft. to 108 ft. it was found that the induced drag at climbing speed was diminished by an amount sufficient to show an improvement of 75 ft. per minute in the rate of climb with one engine in operation.

Attention was directed also to the engine cowling, as it was considered that improvements could be obtained in engine cooling and cooling drag. As a result of considerable research, a new type of cowling, known as the "free-exit" cowl, was evolved and its introduction resulted in a further gain in single-engine climb. Alterations were made also to the exhaust system, which now comprises large-diameter individual pipes in place of the exhaust collector ring used previously. In the "free-exit" cowl, that part of the air which passes through the cylinder heads emerges through a separate annulus behind the rear row of cylinders, while the remainder of the air cools the cylinder barrels and is discharged through a second annulus at the rear of the cowl. The new cowling arrangement is illustrated in Fig. 4, on page 300, from which it can be seen that the outer skin of the cowl is in the form of four hinged panels which can be swung back to give access to the sparking plugs through apertures in the inner skin. These apertures also convey the cylinder-head cooling air from the rear of the heads into the annulus formed between the inner and outer skins whence it flows to the exit immediately behind the rear support ring. The latter also carries the fixed skirt which surrounds the shoulder cowl and thus forms the exit annulus for the main cooling air. The inner skin of the cowl is formed by two removable panels which are located by dowels and secured in position by turnbuckles. The nose cowl is in three pieces and, as shown in Fig. 3, these can be removed to give access to the front of the engine. In addition to giving improved cooling qualities, the new design of cowl represents a saving in weight of 63 lb. for each engine; this has been obtained by the alterations to the exhaust system and the removal of the controllable gills usually associated with Bristol engines. The introduction of the "free-exit" cowl and the alterations to the exhaust system resulted in an improvement of approximately 30 ft. per minute in the single-engine rate of climb.

To improve the single-engine rate of climb still further, larger diameter airscrews were fitted. As will be seen from Figs. 2 and 3, on page 300, the aircraft is of the high-wing type and possesses adequate ground clearance, so that the fitting of 14-ft. diameter airscrews in place of the original 13-ft. 3-in. airscrews presented no major difficulty. The new airscrews are de Havilland constant speed fully-feathering units, and their introduction resulted in an improvement of 30 ft. per minute in single-engine rate of climb. The blades are of N.A.C.A. series 16 section, which is a laminar-flow section giving reduced profile drag; it is understood that it has not been used before in this country. The improvement in performance contributed by the airscrews, therefore, is due partly to the increased diameter and partly to the new blade section.

In addition to the major changes described above, several minor alterations were made to the aircraft during the course of the development programme. Furthermore, certain items of operational equipment were added, some of which detracted from the performance. Nevertheless, the final result was an increase of 100 ft. per minute in single-engine rate of climb. This was a creditable achievement, which led to the granting of a certificate of airworthiness for an all-up weight of 40,000 lb.

Apart from the increased span, the redesigned engine cowlings and the larger airscrews, the New Type 170 aircraft is generally similar to its predecessor. The span, as previously mentioned, is 108 ft., while the overall length and height are 68 ft. 4 in. and 21 ft. 6 in., respectively. The fuselage may be considered as consisting of four assemblies, namely, front or main fuselage, windscreen and hooding, nose fairing and stern frame. The front fuselage extends from the nose of the aircraft to just aft of the passengers' entrance and, with the exception of a few machined fittings and extrusions, is constructed from Alclad. The frames consist of four curved corner pieces, joined by straight channel members, which form the sides, the top and the bottom, respectively, the bottom corner pieces being of heavier gauge than those at the top and having no lightening holes; this form of construction can be seen in Fig. 5, on page 300. The frame members forming the floor are deeper and are reinforced along their upper and lower edges by T-section light-alloy extrusions; the floor is strengthened further by intercostal members of standard channel section joined by cleats to the transverse frames.

Although constructed separately, the windscreen and hood unit is attached permanently to the front fuselage. Apart from the windscreen, the structure is similar to that for the main fuselage, but the flooring of the pilot's cabin is of lighter construction. The stern frame also is similar to the main fuselage, but is provided with a part bulkhead which carries the two forward fin-attachment fittings, while a further bulkhead carries the two corresponding rear fittings. This after bulkhead also carries the tail-wheel upper attachment fittings and is provided with a rectangular aperture for access to the tail unit.

The main plane is in three parts, namely, centre plane and port and starboard outer planes. In plan, the centre plane is rectangular except for the cut-away

portions for fitting to the fuselage. There are two main spars, and the ribs are either of the diaphragm type with flanged lightening holes and vertical Z-shaped stiffeners, or of the skeleton type, and the portion of the centre plane which lies within the fuselage consists of alternate diaphragm and skeleton ribs. The fuel-tank bays are located in the outboard sections of the centre plane, and doors let into the skin plating above the bays give access to the tanks. Outboard from the fuel-tank bays, the ribs are reinforced to take the engine-nacelle structure. The centre plane is bolted to the fuselage through six machined fittings, two of which are on the front spar and four on the rear spar.

Structurally, the outer planes are similar to the centre plane, but, naturally, they decrease in chord and thickness towards the wing tips, the ribs becoming progressively smaller. The wings are joined together at the spars in the usual manner, and the lower attachments for the front spar are designed for use as jacking pads. The ailerons are fabric covered and each consists of a tubular-steel spar to which pressed-diaphragm ribs are riveted at regular intervals. Four landing flaps of the split trailing-edge type are provided and these consist of light-alloy ribs, spars, intercostal members and skin plating. The tail unit comprises a fin and two separate tail planes and is of light-alloy stressed-skin construction; the elevators and rudder, however, are fabric covered. Each tail plane has two spars and the structure incorporates diaphragm-type ribs with flanged lightening holes, which are used in conjunction with angle-section stringers, the assembly being covered with Alclad skin plating.

The aircraft is fitted with Hercules 672 air-cooled radial engines, each of which is rated at 1,690 brake horse-power for take off. Each engine is installed as a completely-cowled power plant embodying its own oil tank, oil cooler, gearbox and engine-driven accessories, and each power plant is fitted to the aircraft nacelle through four pins. The air intakes are fitted to the top of the power plants and a choice of direct, warmed, or filtered air is provided by rotary shutters electrically-controlled from the cockpit. A fire-extinguishing system is fitted to each power plant, and suitably placed flame switches operate a warning light in the cockpit. Injection carburettors are used and fluid de-icing equipment is fitted to both the throttles and the airscrews.

The aircraft can be supplied for carrying either freight or from 32 to 36 passengers; alternatively, it can be arranged for carrying both freight and passengers, in which case a bulkhead divides the hold from the passenger cabin. The bulkhead can be fixed so that a definite number of passengers can be carried, or it may be made movable, to allow the proportions of passengers and freight to be varied. The freighter types of the aircraft are fitted with loading doors in the nose, and Fig. 1, on page 297, shows the aircraft with the doors open and a tractor manœuvring a 25-pounder gun into the hold; it should be mentioned, however, that this illustration shows the aircraft in its original form.

As previously mentioned, the maximum all-up weight is 40,000 lb., of which the payload and fuel represents 13,770 lb. Naturally, the range depends on the payload, but the maximum still-air range is 1,430 miles with a payload of 7,225 lb. With a payload of 10,000 lb., the range is 825 miles, and when the payload is increased to 12,000 lb. the range is reduced to 380 miles. The maximum speed is approximately 224 miles per hour at an altitude of 6,500 ft., while the recommended cruising speed is 162 miles per hour at an altitude of 5,000 ft. The service ceiling at an all-up weight of 35,000 lb. is 24,850 ft., and the time taken to reach an altitude of 10,000 ft. at maximum continuous power is 11 minutes.

GENERATION OF ELECTRICITY.—The official returns rendered to the Electricity Commissioners show that 4227 million kWh of electricity were generated by the authorised undertakings in Great Britain during February, 1948, compared with 3,681 million kWh during the corresponding month of 1947, an increase of 546 million kWh, or 14·8 per cent. This unusually large percentage increase is explained by the fact that during February, 1947, compulsory cuts were made in electricity consumption. During the first two months of 1948 the total amount of electricity generated was 8,768 million kWh, compared with 8,351 million kWh during the corresponding period of 1947, an increase of 417 million kWh, or 5 per cent. The total amount of electricity sent out during the month of February, 1948, was 3,996 million kWh, compared with 3,475 million kWh during the corresponding month of 1947, an increase of 521 million kWh, or 15 per cent. During the first two months of 1948, the total amount of electricity sent out was 8,291 million kWh, compared with 7,878 million kWh during the corresponding period of 1947, an increase of 393 million kWh, or 5 per cent.

BOOKS RECEIVED.

Theoretical Aerodynamics. By PROFESSOR L. M. MILNE-THOMSON. Macmillan and Company, Limited, St. Martin's-street, London, W.C.2. [Price 40s. net.]

Department of Scientific and Industrial Research. Memoirs of the Geological Survey of Great Britain. The Geology of the Country Around Weymouth, Swanage, Corfe and Lulworth. By DR. W. J. ARKELL. H.M. Stationery Office, Kingsway, London, W.C.2. [Price 17s. 6d. net.]

Electric Power Stations. By T. H. CARR. Volume I. Third edition, revised and enlarged. Chapman and Hall, Limited, 37, Essex-street, Strand, London, W.C.2. [Price 36s. net.]

Free Expression in Industry A Social-Psychological Study of Work and Leisure. By JAMES J. GILLESPIE Pilot Press Limited, 45, Great Russell-street, London, W.C.1. [Price 10s. 6d. net.]

British Sources of Reference and Information. A Guide to Societies, Works of Reference and Libraries. Compiled under the Direction of a Committee of Aslib. Edited by THEODORE BESTERMAN. Published for the British Council by the Association of Special Libraries and Information Bureaux, 52, Bloomsbury-street, London, W.C.1. [Price 6s. net (5s. net to members of Aslib).]

Working Manuals for Motor Repairmen. Volume I. *Generators and Motors and Their Applications.* By D. J. DUFFIN. McGraw-Hill Book Company, Incorporated, 330, West 42nd-street, New York 18, U.S.A. [Price 4 dols.] McGraw-Hill Publishing Company, Limited, Aldwych House, Aldwych, London, W.C.2. [Price 24s.]

"The Motor Boat and Yachting" Manual. A Practical Handbook for All Who Are Interested in Motor Boats of Any Type. By the staff of "The Motor Boat and Yachting." Fourteenth edition. Published for Temple Press, Limited, Bowling Green-lane, London, E.C.1, by The English Universities Press, Limited, St. Paul's House, Warwick-square, London, E.C.4. [Price 8s. 6d. net.]

The Locomotives of the Southern Region of British Railways. Compiled and published by W. G. Tilling, 106, Great Dover-street, London, S.E.1. [Price 5s.]

Vibration in Machinery. An Introduction to General Principles. By DR. W. A. TUPLIN. Second edition. Sir Isaac Pitman and Sons, Limited, Parker-street, Kingsway, London, W.C.2. [Price 8s. 6d. net.]

Automobile and Aircraft Engines. By ARTHUR W. JUDGE. Volume I. *The Mechanics of Petrol and Diesel Engines.* Fourth edition, revised and enlarged. Sir Isaac Pitman and Sons, Limited, Parker-street, Kingsway, London, W.C.2. [Price 25s. net.]

Aircraft Sheet Metal. By COLONEL ROLLEN H. DRAKE. The Macmillan Company, 60/62, Fifth-avenue, New York 11, U.S.A. [Price 5.50 dols.] Macmillan and Company, Limited, St. Martin's-street, London, W.C.2. [Price 27s. 6d. net.]

Chemical and Electro-Plated Finishes. The Protective Treatment of Metals. By H. SILMAN. Chapman and Hall, Limited, 37, Essex-street, Strand, London, W.C.2. [Price 30s. net.]

Elementary Fluid Mechanics. By PROFESSOR JOHN K. VENNARD. Second edition. John Wiley and Sons, Incorporated, 440 Fourth-avenue, New York 16, U.S.A. [Price 4 dols.] Chapman and Hall, Limited, 37, Essex-street, Strand, London, W.C.2. [Price 24s. net.]

Ventilation and Air Conditioning. A Textbook for Students and Engineers. By E. L. JOSELIN. Second edition. Edward Arnold and Company, 41 and 43, Maddox-street, London, W.1. [Price 21s. net.]

Concrete for the Contractor. By NOËL D. GREEN. Crosby Lockwood and Son, Limited, 20, Tudor-street, London, E.C.4. [Price 12s. 6d. net.]

Computing Mechanisms and Linkages. By ANTONIN SVOBODA. Edited by HUBERT M. JAMES. McGraw-Hill Book Company, Incorporated, 330, West 42nd-street, New York 18, U.S.A. [Price 4.50 dols.] McGraw-Hill Publishing Company, Limited, Aldwych House, Aldwych, London, W.C.2. [Price 27s.]

Paramagnetic Relaxation. By PROFESSOR C. J. GORTER. Elsevier Publishing Company, Incorporated, Spuistraat 118, Amsterdam-C. Cleaver-Hume Press, Limited, 42a, South Audley-street, London, W.1. [Price 12s. net.]

Yacht Racing. A Textbook of the Sport. By BROOKE HECKSTALL-SMITH. Revised and enlarged by G. SAMBROOKE STURGESS. Third edition. Published for *Yachting World* by Iliffe and Sons, Limited, Dorset House, Stamford-street, London, S.E.1. [Price 25s. net.]

La Photoélasticité. By A. PIRARD. Dunod, 92 rue Bonaparte, Paris (VIe). [Price 1,550 francs.]

Tables numériques universelles des Laboratoires et Bureaux d'étude. By MARCEL BOLL. Dunod, 92 rue Bonaparte, Paris (VIe). [Price 3,200 francs.]

Aircraft Welding. By COLONEL ROLLEN H. DRAKE. The Macmillan Company, 60-62, Fifth-avenue, New York 11, U.S.A. [Price 4 dols.] Macmillan and Company, Limited, St. Martin's-street, London, W.C.2. [Price 20s. net.]

PERSONAL.

The Governing Body of the Imperial College of Science and Technology, South Kensington, London, S.W.7, at their meeting on March 19, appointed AIR CHIEF MARSHAL SIR RODERIC HILL, K.C.B., M.C., A.F.C., to be Rector of the College, as from October 1, 1948, in succession to SIR RICHARD SOUTHWELL, M.A., LL.D., F.R.S.

MR. D. G. SOPWITH, B.Sc. Tech. (Manch.), Wh. Sc., M.I.Mech.E., has been appointed Superintendent of the Engineering Division of the National Physical Laboratory, Teddington, Middlesex, to fill the vacancy caused by the appointment of DR. G. A. HANKINS, Wh. Ex., M.I.C.E., M.I.Mech.E., as Director of Mechanical Engineering Research, Department of Scientific and Industrial Research.

MR. J. W. CURTIS, M.B.E., A.M.I.Mech.E., was inducted as President of the Manchester Association of Engineers, St. John-street Chambers, Deansgate, Manchester 3, on March 19, in succession to MR. F. H. WILLIAMSON, B.Sc. Tech.

MR. H. H. SAUNDERS, O.B.E., M.I.Mech.E., joint managing director of the Vulcan Foundry Limited, has been obliged to retire on medical advice. MR. GERALD COLLINGWOOD, T.D., M.I.Mech.E., hitherto general manager, has been appointed joint managing director in succession to Mr. Saunders.

MR. G. F. THICK, who has been general manager of Macrome Limited, Aldersley, Wolverhampton, since 1945, has been elected to the board of the company.

MR. F. WATKINS, A.F.R.Ae.S., has been elected secretary of the Leicester Branch of the Royal Aeronautical Society. His address is c/o Auster Aircraft Limited, Rearsby Aerodrome, Rearsby, Leicester.

MR. JOHN BELL, M.I.Mech.E., has been appointed deputy chairman of the Projectile and Engineering Company, Limited, Acre-street, Battersea, London, S.W. 8, and is relinquishing the position of managing director as from March 31. Mr. A. J. Chambers, M.B.E., M.I.P.E., has been appointed general manager of the company as from April 1.

MR. J. P. PORTER, B.Sc., M.I.C.E., a principal assistant (technical) in the chief engineer's department, London County Council, has resigned to take up the appointment of chief engineer to the Auckland Metropolitan Drainage Board, New Zealand. He is leaving the Council's service on April 15.

MR. E. S. BRADLEY, M.B.E., district engineer at York, North Eastern Region, British Railways, has been appointed district engineer, Newcastle-upon-Tyne.

MR. W. GLEED has been appointed North London and Home Counties representative for the sale of the compressed-air products of the Atlas Diesel Company, Limited, Beresford-avenue, Wembley, Middlesex, in place of MR. W. L. FAIRLESS, who is joining the South African associate firm of the company.

MR. J. G. MORROW has been re-elected chairman of the Canadian Standards Association, National Research Building, Ottawa, for the year commencing April 1. MR. N. P. PETERSEN and PROFESSOR R. E. JAMIESON have been re-elected vice-chairmen.

MESSRS. J. H. FENNER AND COMPANY, LIMITED, have removed their Belfast branch to more commodious premises at 1, Havelock-street, Ormeau-road, Belfast. The telephone number and telegraphic addresses remain unchanged, namely, Belfast 25409.

MESSRS. DEWRANCE AND COMPANY, LIMITED, have appointed MR. V. FRASER ROSS, 27, Kincora-road, Dublin (Telephone: 35933), to be their representative in Eire.

THE BOARD OF TRADE announce that the section in the Raw Materials Department dealing with cork has been removed from I.C. House, Millbank, to 23, Buckingham-gate, London, S.W.1. (Telephone: VICtoria 7503, Extension 39.)

MESSRS. WADKIN LIMITED, Leicester, have removed their London offices from Kingsway to larger premises at Brookfield House, 62-64, Brook-street, London, W.1. (Telephone: MAYfair 7048-9.)

AN EARLY KITSON LOCOMOTIVE: ERRATUM.—In Mr. P. C. Dewhurst's article on an early locomotive of the Altona and Kiel Railway, on page 244, *ante*, the horizontal and vertical diameters of the elliptical-section boiler barrel were inadvertently transposed; the horizontal diameter should have been given as 3 ft. 1¼ in. and the vertical diameter, 3 ft. 3¼ in.

THE PHYSICAL SOCIETY'S EXHIBITION.—The 32nd exhibition of scientific instruments and apparatus organised by the Physical Society will be held at the Imperial College of Science and Technology, South Kensington, London, S.W.7, from Tuesday, April 6, to Friday, April 9. On the first day, the exhibition will be open from 2 to 9 p.m., and the President of the Board of Trade (the Rt. Hon. J. H. Wilson, M.P.) will perform the opening ceremony at 3 p.m. On the remaining days, the exhibition will be open from 10 to 1 p.m. and 2 to 8 p.m.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scottish Steel.—At least two of the three furnaces laid off last month in the West of Scotland owing to a shortage of scrap have now been restarted, while the new furnace at the Mossend Works of Messrs. Stewarts and Lloyds, brought into production a fortnight ago, has quickly attained the maximum designed production. In a sense, the number of furnaces operating at any time in Scotland, where capacities range from 25 tons to over 100 tons, can be misleading in any assessment of production. Although three furnaces were laid off in February, Scotland made almost its full contribution towards the record-breaking United Kingdom output of over 15,000,000 tons. Pig-iron outputs are being maintained, the principal limiting factor being the restricted supply of metallurgical coke. Iron ore, limestone, and other raw materials continue in fairly satisfactory supply. Substantial exports of steel from Scottish ports during the past week or two are being continued.

Scottish Coal.—Scottish miners, through their leaders, have expressed disapproval of the Government's wage-freezing policy, and in so doing have pointed out that while Scottish miners lead the United Kingdom in coal production, the average wage per shift of all persons in Scottish mines is 4*s.* or 5*s.* less than in other districts in the United Kingdom. This is a question that seems almost certain to be raised nationally in the near future. In the week ending March 13, Scottish deep-mine outputs at 492,300 tons were the best of the year. The previous best of 485,100 tons was recorded in the second week of the year. A marked decrease in the number of unofficial stoppages, together with record productions in Ayrshire and the Lothians, contributed largely to the result. Lanarkshire and Fife were each down on the week by about 1,000 tons. The improved Divisional production has simplified the provision of adequate fuel supplies for consumers, and all classes are comfortably placed for the time being. The export market has been stimulated by a start made with Danish tonnages. The first Scottish consignment, comprising 1,850 tons of Wemyss washed trebles, was loaded at Methil last week. A second cargo of 1,750 tons of washed nuts also left a day or two later, while 1,850 tons of washed nuts was due to load to-day (March 24). A steady trade continues in anthracite and low-volatile gum, with near Continental countries. Recent shipments from Grangemouth included 1,600 tons of the former to Holland, and 2,000 tons of low-volatile gum to France.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—Production in various departments of the steel trades has been pushed forward in an effort to complete specific jobs before the Easter holidays, when a lot of repair and maintenance work is to be undertaken. Pressure for supplies of high-carbon steel in sheet and bar form is unabated; facilities for consumption have been increased at a greater rate than it has been possible to make additions to the capacity at the rolling mills and forges. Manufacturers are looking forward to the suspension shortly of the system of staggered hours; production programmes have been disorganised and dissatisfaction among employees fostered by the operation of the scheme to economise in power. The development of foreign competition in tools and cutlery is reported by some manufacturers. The numerous orders on the manufacturers' books are sufficient to ensure activity for many months, but the flow of new business in steel products is slower than it was. The supply of unskilled labour is now satisfactory, but there is a dearth of highly-skilled men in many works.

South Yorkshire Coal Trade.—Disputes at six South Yorkshire collieries have impeded efforts to increase production, as is usual in the week before Easter. Further demands for locomotive hards have been met, and efforts have been made to effect better deliveries of coking coal. Fine weather has permitted the continued increase of opencast coal production, and ample supplies are being directed to all sections of the home market. Best qualities of coal are being allocated to the export section. Coke is in great demand.

TRACK RELAYING IN POLHILL TUNNEL: ADDENDUM.—The work of relaying the track, renewing the ballast, and improving the drainage in Polhill Tunnel has been completed and the tunnel was fully re-opened to traffic early on Monday, March 22. The Railway Executive, Southern Region, state that the total weight of track relaid was 1,188 tons. By using a special lifting wagon, new 60-ft. lengths of track were laid at a maximum rate of one every three minutes. On an average, 34 lengths of new track were laid in four hours. Relaying was carried out at night, and an automatic tamping machine was used on the ballast during the day.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

General Situation.—North of England iron and steel producing firms have embarrassing delivery obligations and are striving to clear as much tonnage as possible before the end of the month, when uncompleted orders are due for cancellation. The output of Cleveland ironstone is still below requirements, but is increasing, and imports of foreign ores continue to be satisfactory. Scrap is a welcome and cheap substitute for pig iron but the demand continues greatly to exceed the supply.

Foundry and Basic Iron.—Rather better deliveries of foundry pig iron are reaching consuming plants, but supplies still fall short of current requirements and the inadequate tonnage distributable, coupled with the continued scarcity of heavy cast-iron scrap, is gravely impeding the output of light castings and other commodities urgently needed in large quantities for home purposes as well as for export. The position tends to increase the consumption of pig iron at the foundries, but larger deliveries from the blast-furnaces are difficult to secure. Tees-side ironworks are almost wholly engaged in providing metal for the steel-melting shops and most of the foundry pig used by North East Coast firms still comes from the Midlands. Basic-iron makers are supplying their own consuming plants with sufficient tonnage for current needs.

Hematite, Low-Phosphorus and Refined Iron.—The limited make of East-Coast hematite is passing promptly into use and while tonnage distributable is sufficient for the consumers' urgent requirements, larger deliveries would be welcome. The outputs of low- and medium-phosphorus grades of iron are steadily taken up and refined qualities are in good request.

Manufactured Iron and Steel.—Manufacturers of semi-finished and finished iron have as much work in hand as they can deal with and steel-makers have embarrassingly heavy delivery obligations. Conditions regarding steel semies are improving. Re-rollers are now receiving good supplies of billets and slabs from home sources, and better imports of Belgian billets and sheet bars are expected in the near future under the new trading agreement. The demand for maximum deliveries of finished steel continues but the makers point out that the present production cannot be maintained unless considerably more steel scrap is forthcoming. Direct exports of steel are not on a very extensive scale but producers are providing large quantities for shipbuilders, engineers and others engaged on extensive overseas contracts. Shipbuilders hope for steel allocations, over the second quarter of the year, on a scale that will permit the completion of a large volume of new tonnage during the spring and summer months.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

Welsh Coal Trade.—Canada will receive this year about three times as much Welsh anthracite coal as in the past few years. This will follow the conclusion of discussions that have been proceeding for some time and have now reached the stage of finality. One of the greatest difficulties has been that of price, but this has now been satisfactorily overcome. It was stated that the amount of coal likely to be sent from South Wales to Canada this year would be in the region of 150,000 tons. Before the war Canada was a rapidly expanding market for Welsh coals, but since shipments were severely hampered by the war, she has had to draw upon American coals. There seems also to be the possibility of an early expansion of trade with Belgium following the announcement made in Parliament that a new trade agreement being negotiated with that country would provide for increased coal deliveries. The output of coal from the Welsh mines has continued to expand steadily, and the latest figures available show that in the week ended March 13, the production of saleable coal in the area was 454,800 tons, which was more than 3,000 tons above the previous week's total and may be compared with 416,500 tons which was the output in the same period of last year. The supply position was very acute on the market throughout the week. The demand from inland was active and bookings already in hand from this section provided a ready outlet for almost the whole of the coal available. Shipments abroad proceeded along steady lines under the allocations made for the month, but a considerable part of the foreign demand could not be met. Shippers were hopeful, however that increased quantities would become available for export in the next few months.

Swansea Steel-Sheet Industry.—The market report of the Incorporated Swansea Exchange states that, last week, activity in tin-plate was well maintained and home consumers made appreciable purchases for delivery during the next quarter. There was little to spare for the export market, after meeting the home demand. Steel sheets continue to be in great demand and there are eager buyers for all available iron and steel scrap.

NOTICES OF MEETINGS.

IT is requested that particulars for insertion in this column shall reach the Editor not later than Tuesday morning in the week preceding the date of the meeting.

SOCIETY OF INSTRUMENT TECHNOLOGY.—Tuesday, March 30, 7 p.m., Manson House, Portland-place, W.1. "An Experimental Electrical Pressure Meter," by Messrs. S. S. Carlisle and B. O. Smith.

ROYAL UNITED SERVICE INSTITUTION.—Wednesday, March 31, 3 p.m., Whitehall, S.W.1. "Atomic Energy," by Professor H. S. W. Massey, F.R.S.

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS.—*Preston Branch:* Wednesday, March 31, 7.30 p.m., White Bull Hotel, Church-street, Blackburn. "District Heating," by Mr. J. F. Bridge.

INSTITUTE OF BRITISH FOUNDRYMEN.—*London Branch:* Wednesday, March 31, 7.30 p.m., Waldorf Hotel, Aldwych, W.C.2. "Production Planning for the Foundry," by Mr. W. A. Turner. *East Midlands Branch:* Saturday, April 3, 6 p.m., School of Arts, Green-lane, Derby. Annual Meeting and Short Paper Competition. *Lancashire Branch:* Saturday, April 3, 3 p.m., Engineers' Club, Manchester. Annual Meeting. "Making a Turbine Case for Hydro-Electric Plant," by Mr. T. Rigby. *East Anglian Section:* Wednesday, April 7, 7.30 p.m., Central Library, Ipswich. Annual Meeting.

INSTITUTION OF ELECTRICAL ENGINEERS.—Thursday, April 1, 5.30 p.m., Victoria-embankment, W.C.2. "Analysis-Synthesis Telephony, with Special Reference to the Vocoder," by Mr. R. J. Halsey and Dr. J. Swaffield. *Measurements Section:* Friday, April 2, 5.30 p.m., Victoria-embankment, W.C.2. Discussion on "High-Speed Recording of Optical and Electrical Transients," opened by Mr. H. A. Prime. *North-Eastern Centre:* Monday, April 5, 6.15 p.m., Neville Hall, Newcastle-upon-Tyne. Annual Meeting. "A New Electron Microscope," by Mr. M. E. Haine. *South Midland Centre:* Monday, April 5, 6 p.m., James Watt Institute, Birmingham. "Large Vertical-Shaft A.C. Generators Driven by Water Turbines," by Messrs. E. M. Johnson and C. P. Holder. Also at *North-Western Centre:* Tuesday, April 6, 6 p.m., Engineers' Club, Manchester. *East Midland Centre:* Tuesday, April 6, 6.30 p.m., Loughborough College, Loughborough. "The High-Pressure Mercury-Vapour Discharge," by Messrs. V. J. Francis and W. R. Stevens.

INSTITUTION OF CIVIL ENGINEERS.—*North-Western Association:* Thursday, April 1, 6.30 p.m., Engineers' Club, Manchester. "The Development of Motorway Projects," by Mr. F. D. C. Henry.

INCORPORATED PLANT ENGINEERS.—*Glasgow Branch:* Thursday, April 1, 7 p.m., 39, Elmbank-crescent, Glasgow. "Fuel Efficiency and the Maintenance Engineer," by Mr. J. B. M. Mason. *Manchester Branch:* Tuesday, April 6, 7.15 p.m., Engineers' Club, Manchester. "Application of Friction Linings on Plant," by Mr. A. D. Aspell. *London Branch:* Wednesday, April 7, 7 p.m., Royal Society of Arts, John Adam-street, W.C.2. "Maintenance of Plant in the Drug Industry," by Mr. H. E. Chant.

INSTITUTION OF MECHANICAL ENGINEERS.—Friday, April 2, 5.30 p.m., Storey's-gate, St. James's Park, S.W.1. Meeting in conjunction with *Applied Mechanics Group.* "Researches into the Deformation of Metals by Cold Rolling," by Dr. Hugh Ford. "Calculation of Roll Force and Torque in Cold Strip Rolling with Tensions," by Mr. D. R. Bland and Dr. Hugh Ford. Friday, April 9, 5.30 p.m., Storey's-gate, S.W.1. "District Heating," by Mr. A. Stubbs. *Internal Combustion Engine Group* and *Automobile Division:* Tuesday, April 6, 6 p.m., Storey's-gate, S.W.1. "Piston Ring Movement During Blow-by in High-Speed Petrol Engines," by Dr. P. de K. Dykes.

JUNIOR INSTITUTION OF ENGINEERS.—Friday, April 2, 6.30 p.m., 39, Victoria-street, S.W.1. Discussion on "Some Recent Advances in Science," opened by Mr. L. H. A. Carr. *Midland Section:* Wednesday, April 7, 6.30 p.m., James Watt Institute, Birmingham. "Development of the Gas Turbine," by Dr. E. A. Watson and Mr. O. N. Lawrence.

SOCIETY OF ENGINEERS.—Monday, April 5, 5.30 p.m., Geological Society, Burlington House, Piccadilly, W.1. "Filtration," by Mr. C. G. Vokes.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND.—Tuesday, April 6, 6.30 p.m., 39, Elmbank-crescent, Glasgow, C.2. Annual Meeting. "Standardisation," by Mr. S. J. Harley.

SHEFFIELD METALLURGICAL ASSOCIATION.—Tuesday, April 6, 7 p.m., 198, West-street, Sheffield. "Precision Casting," by Mr. H. Evans.

WEST RIDING FEDERATION OF ENGINEERING SOCIETIES.—Tuesday, April 6, 7.30 p.m., Technical College, Bradford. "High-Speed Photography in Engineering," by Mr. George A. Jones.

ROYAL SOCIETY OF ARTS.—Wednesday, April 7, 2.30 p.m., John Adam-street, W.C.2. "Craftsmanship: Codes of Work in Glass History," by Mr. W. A. Thorpe.

CIVIL TRANSPORT AIRCRAFT.

THE BRISTOL AEROPLANE COMPANY, LIMITED, FILTON.

(*For Description, see Page* 297.)

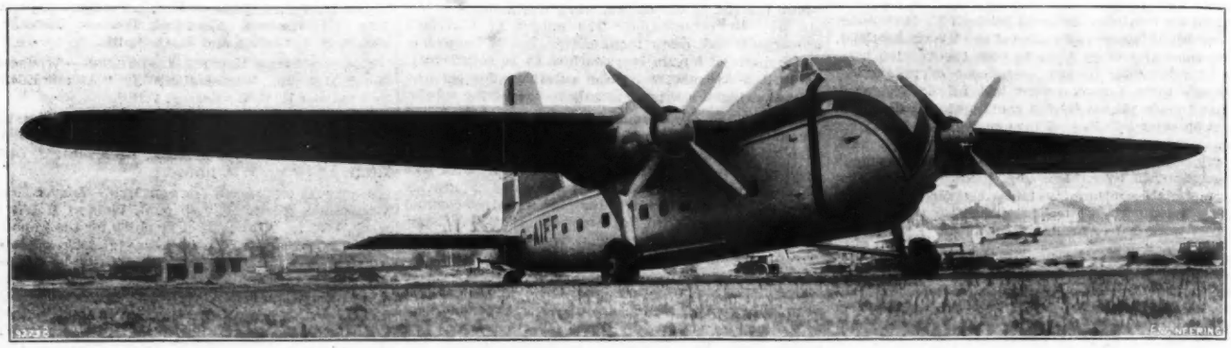


FIG. 2. THREE-QUARTER FRONT VIEW OF AIRCRAFT.

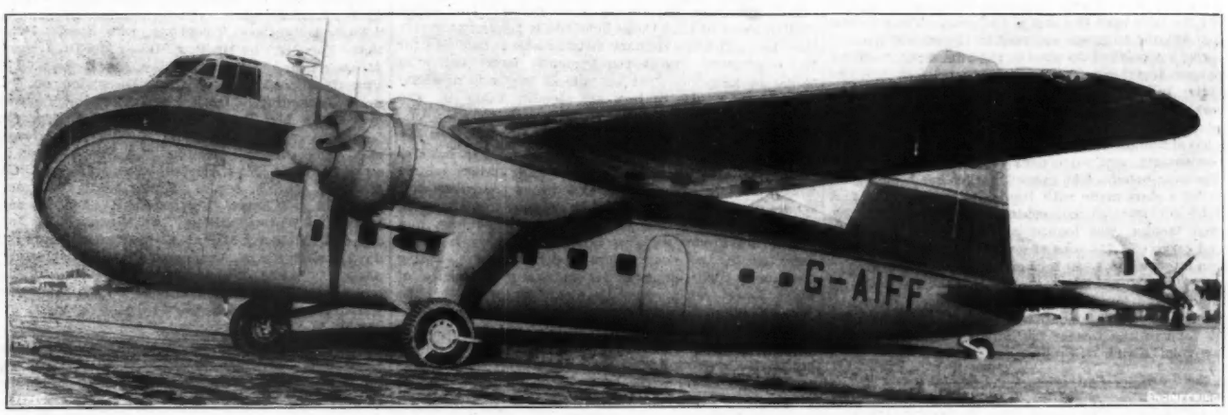


FIG. 3. PORT SIDE OF AIRCRAFT.

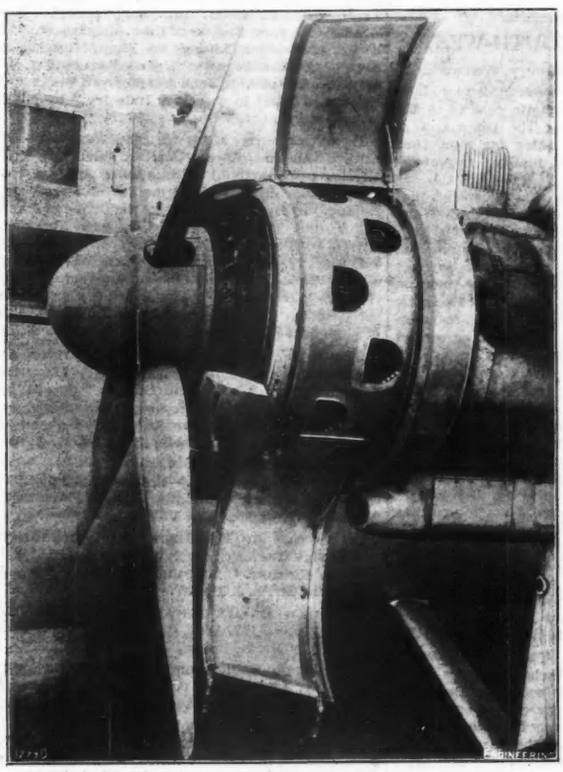


FIG. 4. ENGINE COWLING OPEN FOR INSPECTION.

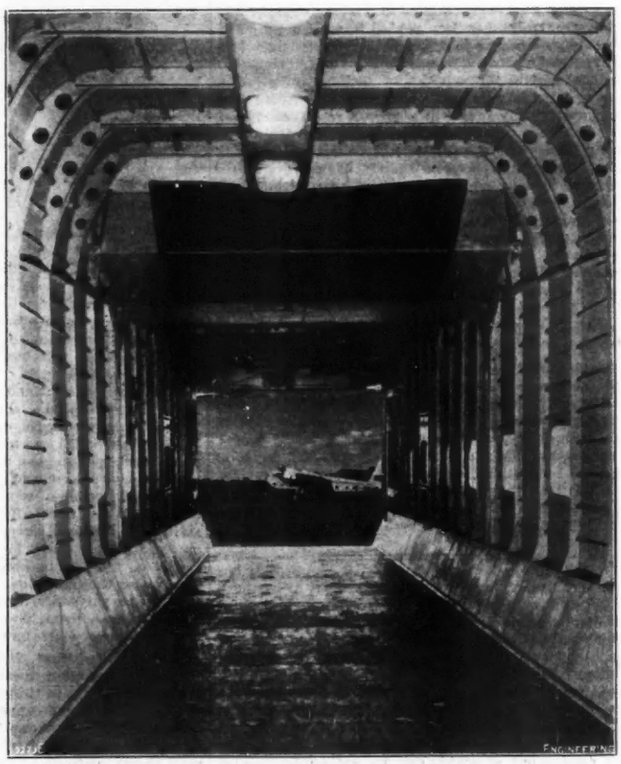


FIG. 5. INTERIOR OF FUSELAGE.

ENGINEERING.

35 & 36, BEDFORD STREET, STRAND, LONDON, W.C.2.

We desire to call the attention of our readers to the fact that the above is the address of our Registered Offices, and that no connection exists between this Journal and any other publication bearing a similar title.

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Classified advertisements intended for insertion in the current week's issue must be received not later than first post Wednesday.

"Copy" instructions and alterations to standing advertisements for display announcements must be received at least 10 days previous to the date of publication, otherwise it may be impossible to submit proofs for approval.

The Proprietors will not hold themselves responsible for advertisers' blocks left in their possession for more than two years.

INDEX TO VOL. 164.

The Index to Vol. 164 of ENGINEERING (July-December, 1947) is now ready and will be sent to any reader, without charge and postage paid, on application being made to the Publisher. In order to reduce the consumption of paper, copies of the Index are being distributed only in response to such applications.

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ENGINEERING

FRIDAY, MARCH 26, 1948.

VOL. 165. No. 4287.

REPARATIONS IN KIND.

IN March, 1946, the Allied Control Council agreed on a plan restricting the future level of German industry and fixing the amount of German capital equipment available as reparations. Events since that date have disrupted any over-all proposals, but the Inter-Allied Reparation Agency, which was set up in Brussels two years ago, has operated successfully and is carrying out the task for which it was constituted. The Agency is in the fortunate position of being independent from interference by Foreign Ministers' Conferences, or other bodies which flounder in the morass of international politics; its activities are confined to what is essentially a technical sphere. The business of the Agency is to allot German capital equipment fairly among claimant nations. It is not concerned with deciding what machines or factory installations may be removed from Germany; that is a matter for the Control Council. The Agency is advised by the Council what plant is available for reparations and it decides what particular country has best claim to any specific machine or factory installation and is likely to use it most effectively. Again, it is fortunate in the fact that it is not concerned with the allocation of material to either Russia or Poland.

It is clear that the Agency has a task of some delicacy. Most nations may naturally be expected to try to get anything they can and it is necessary to assess the validity of all claims made. The purpose of the distribution is to assist in the rehabilitation of European economy generally; not to enable some country to establish a new industry of which it has had no previous experience. Allocation is made in terms of the extent to which the productive capacity of a country has suffered by the removal of plant by Germany, or the deterioration of machines owing to intensive use. Destruction by aerial bombing, and by artillery fire and land fighting, is also an important factor in the assessment of need. That there have been few cases of appeal against the decisions of the Agency shows that it is carrying out its task with judgment and impartiality.

Interesting information about the allocations made and the purposes to which they are being put is contained in a report which has recently been prepared by the Agency for the benefit of the member Governments. Naturally, countries which were physically submerged by the tide of war suffered greatest injury and may make the stronger case. The Netherlands Government reported that the Germans removed as much as 80 per cent. of the machinery of certain industrial plants and the French Government stated that some 45,000 machine tools were taken away. At the other end of the scale, Australia, New Zealand and India, while not able to make a case based on direct destruction or the filching of plant, point out that their machine-tool and other manufacturing equipment suffered heavy depreciation owing to intensive use during the war, at a time when proper maintenance was impossible. United States Government claims have been adjusted to contribute as far as possible to the economic recovery of the Allied nations which suffered most severely from the war, and have renounced much of their share of capital equipment, taking mainly scientific and research materials.

Great Britain occupies an intermediate position between occupied territories and physically undamaged countries. Aerial destruction was very heavy and the damage caused by cross-Channel artillery fire was far from negligible. The intensive use of manufacturing equipment, with the deferment of proper maintenance, was also carried to a stage that was probably not reached elsewhere. Many member Governments pointed out that machines which may represent a vital link in some manufacturing process cannot be obtained at the present time from normal sources without delays which may extend up to three years. This point is well illustrated by the plant which has been allotted to Great Britain. This includes some hundreds of machine tools. One of these was a large boring machine which was delivered to the firm concerned on September 1, 1947, and was in operation by October 13. This enabled important works equipment to be completed and installed during the Christmas break. Had the machine not been available, there would have been a delay of six months, until the summer holidays, as the installation could be carried out only when the works was closed down. Attempts had been made to purchase a new boring machine, but the earliest delivery promised was three years. A number of similar cases are quoted in the report.

In addition to allocating large numbers of individual machines, the Agency is concerned with many complete plants and power-station equipments. An example of the latter is furnished by a 30,000-kW power plant from a Mannheim factory. This has been transferred to the French Government for re-erection at Caen. During the Normandy fighting the Caen station was almost completely destroyed. It has now been rehabilitated to the extent of furnishing an output of 12,000 kW, but the estimated demand of the region is 80,000 kW. Quotations for new plant from French and Swiss firms have specified delivery dates 2½ to 3 years ahead, but the transferred German plant is expected to be in operation this year. Three other thermal generating plants have also been allotted to France for re-erection at manufacturing works at St. Clair du Rhone, Toulouse and Marseilles.

A large number of the complete works plants which have been transferred have been concerned with chemical manufacture; thus the installations obtained by France up to November, 1947, were in the ratios of nine for electrical equipment, 22 for mechanical equipment and 165 for chemical equipment. Chemical plant is one of the few types of manufacturing plant for which the United States Government have bid; they claimed certain equipment from the Paraxolwerke, which manufactured formaldehyde and pentaerithritol, $C(CH_2OH)_4$. This latter material is a substitute for glycerine and is used in the production of moulding powers for plastics. The United States claim was based on the fact that the equipment is superior to comparable plant built in that country; the main installation was, however, allotted to France. The United States also bid for aluminium-foil plant, which was formerly imported from Germany. The most important complete manufacturing plant allocated to Great Britain is that of the Hahn und Tessky Indexwerke, who made the Index automatic screw

machines. Before the war, this country was the largest user of these machines outside Germany. The plant has been acquired by B.S.A. Tools, Limited, who have formed the Index Automatic Machine Company to operate it. The plant is now being installed and it is expected that deliveries will begin towards the end of this year. It is stated that certain chemical plant allocated to Great Britain will enable products to be manufactured which at present are obtained from the Western Hemisphere at a cost of 2,500,000 dols. per annum. The allocation of industrial material to Britain has had to be related to the large number of merchant ships received as reparations.

Some of the keenest competition among the nations has been for specialised plants for the production of ball and roller bearings, crankshafts and optical instruments. As Germany was one of the leading suppliers of anti-friction bearings, many countries have found themselves in difficulties owing to the shortage of these essential components. The reports record the allocation of only one ball-bearing plant, which has been passed to Czechoslovakia, but two crankshaft plants are mentioned. One was supplied to France and put into operation in 1947. Some 320 machines from the Kurbelwellenwerke, for the production of crankshafts, were allotted to the Netherlands in April, 1947. This country also received an optical-instrument plant. Some countries are naturally interested in general-purpose machine tools more than specialised plants. Examples are furnished by Australia, New Zealand, India, Norway, Belgium and Luxemburg. The replacement of worn-out equipment is hampered not only by the difficulty of obtaining deliveries within a reasonable period, but also, in many cases, by the impossibility of financing purchases from hard-currency countries. It might be expected that the excessive wear from which the machine-shop equipment of the Allied nations suffered was characteristic of German workshops also, and it would appear that some of the material available cannot be in good condition. This matter is not, however, referred to in the report in any way. In connection with the demand for general-purpose machine tools by Luxemburg, Belgium and Norway, the first-named reported that the Allied bombing of German communications resulted in the total destruction of the two largest railway workshops in the country and others were badly damaged during the Rundstedt counter-offensive in December, 1944. In Belgium, very large numbers of machine tools were damaged or looted by the Germans. For a high-speed drilling machine allotted to this country, bids were put in by no fewer than 29 firms.

In the case of Norway, it is stated that 95 per cent. of the capital equipment which has been allotted consists of general-purpose machine tools. The total equipment of this type in the country was reduced by 45 per cent. during the war. As in Belgium, the shortage is illustrated by the competition for any machine which becomes available. Lathes are in great demand, and for one machine there were 120 bids. The main type of equipment, other than machine tools, which has been supplied to the country is for the production of formaldehyde. Harbour equipment and shipyard machinery are other types of material for which many nations have put in claims. The destruction at the Channel ports can have left little mechanical equipment in serviceable condition, but German ports were in a similar condition, so that there are probably few, if any, harbour cranes or similar types of plant available for reparations. The report mentions this matter of port and shipyard equipment and it is stated that in France alone, the dockyards and shipbuilding slips at Rouen, Le Havre, Cherbourg, Brest, Lorient, Nantes, St. Nazaire, and Toulon were almost totally destroyed. No doubt general-purpose machine tools will, to some extent, serve to rehabilitate shipyard plants, but there is no record in the report of the delivery of specific shipyard machinery, though Denmark claimed some on the score of the intense exploitation of Danish yards by the Germans. Incidentally, the report does not record the delivery of material of any kind to Greece, Yugoslavia or Denmark, but it is not altogether clear if the information given is complete or merely illustrative.

CENTRALISED ELECTRICITY SUPPLY.

THE Central Electricity Board will cease to exist on Thursday, April 1, their assets on that date being, in common with those of the other supply undertakings in the country, vested in the new British Electricity Authority. It is therefore appropriate that their twentieth Annual Report,* which is published this week, should deal with the objects for which the Board was originally established and the extent to which those objects have been achieved. As is common knowledge, the task of the Board, as laid down in the Electricity (Supply) Act, 1926, was to build a national network of transmission lines, to control electrical generation throughout the country, to standardise the frequency and to provide the authorised undertakings with supplies of electricity for local distribution. Two major economies, it was anticipated, would thus be attained—a capital saving owing to the reduction in the proportion of spare plant it would be necessary to maintain and an annual saving in the cost of generation. To perform this manifold task a new organisation with its own policy and methods had to be built up financed and administered. Nevertheless, within three months of the first meeting of the Board on March 3, 1927, a scheme for Central Scotland had been adopted and the first contract was placed on December 5 in the same year. By July 31, 1931, nine schemes, covering the whole of Great Britain, except the North of Scotland, had been adopted, while the last tower of the grid as originally planned was erected on September 5, 1933.

The speed with which this work, involving some 3,000 miles of 132-kV transmission lines and 270 substations, was carried out would in any case have reflected credit on the skill and energy of the engineers and contractors concerned. It was, however, the more praiseworthy since the Board had no precedent to follow and much of the early work was therefore of a pioneering and experimental character. For instance, the adoption of multiple earthing and the employment of steel-cored aluminium conductors were both novel features, as was the use of galvanised-steel towers. Further illustrations of the Board's progressive outlook are the employment for the first time in this country of 132-kV cables, the introduction of protective gear of a type which has enabled 95 per cent. of the faults occurring to be cleared correctly, and the doubling of the reliable rupturing capacity of the switchgear installed. Moreover, researches into the methods of communication necessary for the control of an interconnected power system have resulted not only in the evolution of a satisfactory service, but in the possibility of applying the principles involved to the remote control of equipment.

Some interesting developments have also taken place on the operating side; for while originally the country was divided into nine areas, these have subsequently been reduced to six. National control of generation was first imposed on area control in 1938, while during the 1939-45 war the grid was normally operated as a single unit. This practice was adopted primarily to enable the generating plant available to be more effectively pooled, to improve the mutual assistance between areas, to increase operating economies and to substitute the transmission of electricity for the transport of coal. These requirements have necessitated the reinforcement of a number of the inter-area lines, while further strengthening is proposed by superimposing a separate system, designed for operation at 264 kV, on the existing 132-kV grid. It may therefore be said that the grid has succeeded in one of its main objects of enabling generation to be concentrated on the most suitable sites and of permitting the smaller and less efficient stations to be shut down. It is satisfactory to be able to record that this object has been achieved with the close co-operation of the individual undertakings, both publicly and privately owned. During the war, in particular, these bodies showed themselves, when necessary, willing to sacrifice their immediate interests and so to contribute greatly to smooth operation. In fact, the attitude of the undertakings to the Board has gradually changed from the thinly veiled hostility and armed neutrality of the early days to the friendliness which reflects credit on the tact and single mindedness of those concerned. This attitude has persisted in spite of the difficulties arising from shortage of plant and the intricate arrangements which have had to be devised for shedding load and staggering working hours.

Judged by the criterion of financial results the 21 years' work of the Board may also be written down as successful. During the first ten years of its existence the net annual saving to the supply industry brought about by the existence of the grid amounted to 17 per cent. of the costs of production which would otherwise have been incurred. Based on the output during 1937-38 and the average price levels during the period 1927-30, this was equivalent to a saving during the former year of some 8,200,000*l*. During and since the war, the statistical bases for making similar calculations have not been available; and a major distorting factor has been the interruption of the programme of plant installation. There can be no doubt, however, that the expansion of demand during the war would have required a much greater increase in plant had there been no grid, and that the effects of the shortage and poor quality of fuel were greatly reduced by its existence. There is no reason to suppose, therefore, that since 1937-38 the relative economies have in any way diminished. As some proof of this contention it may be mentioned that while in 1925-26 the average price charged by the electricity supply industry to its consumers was 1·65*d*. per kilowatt-hour, by 1946-47 this had fallen to 1·08*d*. per kilowatt-hour sold, in spite of the fact that in the interim the price of fuel had increased two and a half times. The results of the Board's work are similarly reflected in the rapid growth which has taken place in the consumption of electricity. This is shown by the fact that while in the year ended December 31, 1926, 7,040 million kilowatt-hours were generated in the public supply stations of the country, the corresponding figure in the year ended December 31, 1947, was 42,579 million kilowatt-hours.

Turning to the events of the past year, reference must first be made to the fuel crisis, of the imminence of which the Board had warned the Ministry of Fuel and Power early in 1946. Nevertheless, the policy of limiting fuel stocks to four weeks' consumption at the beginning of the 1946-47 winter period was persisted in, the result being that on February 7, 1947, the stocks at the generating stations controlled by the Board had fallen to under 900,000 tons, or less than 1·5 weeks' requirements. As is well known, this dangerous situation was partly brought about by abnormally bad weather and necessitated restrictions of varying severity, on both industrial and domestic users, some of which continued throughout the summer. The year was also notable for the widespread load shedding which was necessary in the early months. This arose, of course, from shortage of generating plant, a shortage which was primarily due to the restrictions imposed by the Government during the war on the Board's programmes for the provision of additional generating plant. The result was that load shedding was necessary on 122 occasions, compared with 54 in 1946 and four in 1945. As an indication of the amounts involved, however, it may be mentioned that the maximum reduction the undertakings in any area were required to make was 30 per cent., while the maximum load shed at any time was some 1,831 MW, or about 21·2 per cent. of the total load on the system. This figure compares with a maximum of 10·4 per cent. in 1946. What is more significant is that it was necessary to shed up to a maximum of 630 MW on 22 occasions during the main summer overhaul period, while throughout that period the system had to be operated with little or no margin, in order to ensure that the maximum possible amount of plant should be available during the winter of 1947-48. Unfortunately, the Government's economic policy renders it likely that these periods of stringency and difficulty will recur for a number of years. That, however, is one of the few unsatisfactory legacies that the Board is leaving to the new Electricity Authority.

* Whitehead Morris Limited, 72-73, Fleet-street, London, E.C.4. [Price 1s. net.]

NOTES.

THE ROYAL SOCIETY: ELECTION OF FELLOWS.

AT their meeting on Thursday, March 18, the Royal Society elected into the Fellowship 25 men and women who have attained eminence in various branches of science. The new Fellows include Dr. T. E. Allibone, M.I.E.E., director of the Research Laboratories of Associated Electrical Industries, Limited, Aldermaston, who has made many contributions to the application of high-voltage phenomena; Dr. F. P. Bowden, lecturer in physical chemistry, the University of Cambridge, author of contributions on the study of friction and lubrication; Mr. Hayne Constant, M.A., M.I.Mech.E., F.R.Ae.S., Deputy Director (Research), National Gas Turbine Establishment, who has carried out studies in the applications of thermodynamics and aerodynamics to aircraft engines; Dr. S. F. Dorey, Wh.Ex., M.I.C.E., M.I.Mech.E., M.I.N.A., chief surveyor, Lloyd's Register of Shipping, who has made many contributions to the science of marine engineering; Dr. E. H. Farmer, assistant director and senior organic chemist, the British Rubber Producers' Research Association, Welwyn Garden City, who is responsible for experimental studies of complex unsaturated hydrocarbons and related natural products; Professor O. R. Frisch, Jacksonian Professor of Physics, Cavendish Laboratory, Cambridge, who has done much work on fission processes in nuclear physics; Professor W. H. Heitler, Institute for Advanced Studies, Dublin, who has made important contributions to the science of theoretical physics; Mr. G. M. Lees, chief geologist to the Anglo-Iranian Oil Company, Limited, who is responsible for investigations in stratigraphical and structural geology, particularly in relation to oilfields; Mr. J. W. Ryde, senior physicist in the research laboratories of the General Electric Company, Limited, Wembley, who has made many contributions to pure and applied physics; and Mr. E. W. R. Steacie, director, Division of Chemistry, National Research Council, Canada, who is responsible for a number of researches on gaseous chemical reactions.

INDUSTRY AND THE NOBEL PRIZES.

A special meeting of the Federation of British Industries, in honour of the two British recipients of 1947 Nobel Prizes for Science—Sir Robert Robinson, M.A., D.Sc., President of the Royal Society, and Sir Edward Appleton, G.B.E., K.C.B., F.R.S., secretary of the Department of Scientific and Industrial Research—was held at the Royal Institution, London, W.1, on the afternoon of March 19. The chair was taken by Sir Frederick Bain, M.C., President of the Federation, who in offering Sir Robert and Sir Edward the congratulations of British industry, said that, since 1901, this country had received 36 Nobel Prize awards in the five different categories, but not since 1904, when Sir William Ramsay and Lord Rayleigh received their awards, had the Prizes for chemistry and physics come to this country undivided and undisputed. Robinson and Appleton now shared the distinction of Ramsay and Rayleigh. Sir Robert Robinson then delivered an address on "The Scope of Organic Chemistry," in the course of which he referred to the importance of research in organic chemistry both in war and in peace-time, and put in a plea for the increase of the remuneration of all teachers of the subject and the enlargement and modernisation of the university departments in which organic chemistry was taught. In a brief tribute and in proposing a vote of thanks to Sir Robert, Sir Wallace Akers C.B.E., Director of Research of Imperial Chemical Industries, Limited, said that when approaching some of the most complicated problems Sir Robert always employed methods of real beauty and elegance. Sir Edward Appleton then delivered an address on "The Scientist in Industry," during which he said that the scientist in industry must fulfil three functions. First, he must provide a scientific service for his industry or firm; secondly, he must carry out research aimed at the devising of new and better processes, goods and materials; and thirdly, he should also be a contributor to the world's scientific knowledge. In proposing a vote of thanks to Sir Edward, Sir William Larke, K.B.E., chairman of the Industrial Research Committee of the Federation, said that it was fitting that industry should pay tribute to the labours of the two Nobel Prizemen in that building in which so much fundamental research work had been carried out. The meeting was terminated by Sir Henry T. Tizard, F.R.S., chairman of the Scientific Advisory and Industrial Productivity Committees, who proposed a vote of thanks to the chairman. In the evening of the same day, the Federation gave a complimentary dinner in honour of the two Prizemen at the Mayfair Hotel, W.1, when the guests included the Prime Minister (Mr. Clement Attlee) and other members of the Government, Sir John Anderson, F.R.S., and Mr. H. V. Tewson, C.B.E., general secretary of the Trades Union Congress. To the toast of "The Nobel Prize Winners of 1947," proposed by Mr. Attlee, and seconded by Sir John Anderson, both Sir Robert Robinson and Sir Edward Appleton responded. Sir Robert traced in brief outline a number of outstanding developments in organic chemistry, and their influence on the progress of industry; and he urged that there should be no relaxation, but a broad and general intensification, in the prosecution of further fundamental research. Sir Edward Appleton, reviewing in turn the most significant phases of his own researches, said that they had been profoundly influenced by the scientific work of three Scotsmen—Balfour Stewart, who first suggested that there might be an electrically-conducting layer in the upper atmosphere, C. T. R. Wilson ("the greatest artist among experimental physicists"), who developed the cloud chamber, and Charles Chree, who elucidated the regularities and irregularities in the earth's magnetism. Of the situation created by the advances in nuclear physics Sir Edward said that he stoutly supported the principle of international control at the present stage, but looked forward hopefully to an era in which it would not be necessary. The toast of "British Industry" was proposed by Mr. H. V. Tewson, and acknowledged by Sir Frederick Bain, who took the opportunity to call upon the seven former Prizemen present to stand and be introduced to the company.

THE INSTITUTION OF MECHANICAL ENGINEERS.

The results of the Council elections of the Institution of Mechanical Engineers for 1948 was declared at the annual general meeting held at Storey's-gate, London, S.W.1, on Friday, March 19. The following members were elected: President, Major William Gregson, M.Sc.; vice-presidents, Dr. H. J. Gough, C.B., M.B.E., F.R.S., and Mr. A. Roebuck; members of Council, Dr. D. S. Anderson, B.Sc., Dr. R. W. Bailey, Wh.Sc., Vice-Admiral (E) D. C. Ford, C.B., C.B.E., Dr. H. E. Merritt, M.B.E., the Honourable J. K. Weir, C.B.E., B.A., Dr. W. Ker Wilson, Wh. Ex., and Mr. D. Rebbeck, M.A. (Cantab.), (associate member). In accordance with By-law 35, the following past-presidents continue to serve as members of Council: Lord Dudley Gordon, D.S.O., Mr. O. V. S. Bulleid, Sir Harry Ricardo, B.A., LL.D., F.R.S., and Professor Andrew Robertson, D.Sc., Wh.Ex., F.R.S.

PROPOSED FREQUENCY-MODULATED BROADCAST TRANSMITTING STATION.

On Tuesday, March 16, it was announced that the British Broadcasting Corporation had begun work on the construction of a transmitting station near Wrotham, Kent, at which frequency modulation would be used. Although technical details about this interesting project are not available, it may be recorded as an important development in the history of broadcasting, and one which, by bringing into use a new band of wavelengths, will do much to remove the limitations brought about by international wavelength troubles. As is well known, ordinary sound broadcasting throughout the world is transmitted by amplitude modulation, "medium" wavelengths, such as 350 m., or "long" wavelengths, such as 1,500 m., being almost universally employed. These bands are naturally overcrowded, and any system which would enable alternative wavelengths to be used is therefore worth consideration. When, therefore, it was found some years ago that the "sound" for the television programme, which for convenience was being transmitted on a wavelength of 6 or 7 m., had a practical range of 40 miles or more, it seemed probable that auxiliary transmitters of greater powers than the 3 kW sets used at Alexandra Palace would enable good sound broadcasts to be transmitted on these short wavelengths to distances comparable with those possible with the ordinary medium wavelengths. It was also clear that if frequency modulation were used for transmission, the interference due to motor cars and electro-medical apparatus, experienced with short wavelengths and amplitude modulation, would be reduced. Other advantages would be a greater freedom from background noise and the transmission of a wider band of audio frequencies, thus leading to a more faithful reproduction of music. It was also claimed that longer ranges could be obtained, other factors being equal, with frequency than with amplitude modulation. Although work on this subject, generally speaking, had to be suspended during the war, the British Broadcasting Corporation renewed their investigations in 1945; and for the past eighteen months have been carrying out regular experimental transmissions of the Third Programme from Alexandra Palace on a wavelength of 3·3 m. It is proposed that initially Wrotham shall also be used for experiments especially to determine the degree of interference from Continental stations.

THE WHITWORTH SOCIETY.

Reverting to the pre-war practice of holding the annual commemoration meeting on March 18, the month and day on which the Whitworth scholarships were founded, in 1868, the Whitworth Society met for luncheon at the Holborn Restaurant, London, on Thursday of last week, Professor Andrew Robertson, the President, being in the chair. The difficulties of recent years have prevented regular observance of this date, but it is hoped to hold the meetings at the appropriate time, and with regularity, in the future. After the president had proposed the loyal toast and that to "The Memory of our Founder," Professor S. J. Davies proposed "Success to the Whitworth Society." He referred to the changes in the regulations governing the award of scholarships, which come into operation this year. The matter was the subject of some discussion by the members generally, towards the end of the meeting, particularly in connection with the point that future Senior Scholars will not necessarily be required to have had workshop experience. The points raised were dealt with by Dr. F. T. Barwell, the hon. secretary, who pointed out that a man without workshop qualifications who won a senior scholarship would be required, when holding the scholarship, to enter an engineering works for practical experience for a period of at least twelve months. He added that the changes in the regulations had been made with the concurrence of the Committee of the Whitworth Society. This whole matter was discussed in some detail on page 385 of our 163rd volume (1947). In replying to this toast, Professor Robertson referred to the fact that competition for Whitworth scholarships was not so widespread as at one time, and suggested that members of the Whitworth Society should make a point of bringing the advantages and possibilities of the Whitworth competition to the notice of promising juniors. The falling off may be attributed to the fact that the scholarships are now awarded on the results of special examinations; at one time they were based on the examinations of the old Science and Art Department, which were held in a very large number of centres distributed throughout the country. The object of the Whitworth Society Prizes, which are awarded to successful students in the National Certificate examinations, is to encourage interest in the Whitworth Competition. Professor Robertson also announced that the summer meeting would be held in Bristol on May 26. The last toast, "Our Guests, the New Whitworth Scholars," was proposed by Dr. H. L. Guy, F.R.S., and was responded to by the only new scholar present, the others having been prevented from attending by illness or other cause.

LETTERS TO THE EDITOR.

PETER WILLANS.

TO THE EDITOR OF ENGINEERING.

SIR,—It is a strange coincidence that the letter on my father, P. W. Willans, from my old friend, Mr. E. S. Ormsby, should be published in the same issue as that of Dr. W. A. Tuplin on locomotive tests. The conclusion to be drawn from reading both letters is, I regret to say, unfavourable to the steam locomotive industry.

In 1888, my father, as Mr. Ormsby says, carried out tests on one of his steam engines which have provided the datum for most of the innumerable detail and basic improvements that have been made during the 60 years which have elapsed since the reading of his paper to the Institution of Civil Engineers. In contrast to this, we see all too clearly that it is not until the steam locomotive is nearing its end that methodical testing is being indulged in; and the results may or may not be applied. The steam locomotive was substantially in the same form in 1888 as it is at the present time; apart from superheating, modifications have been detail, rather than fundamental.

One realises now what a chance was missed when Sir Cecil Paget's revolutionary locomotive was quietly put out of the way. Perhaps its eight single-acting uniflow cylinders, if provided with a better valve gear, might have been the way, to quote Dr. Tuplin, "of hauling 500 tons at 100 m.p.h. with a locomotive weighing about 105 tons, with fewer than eight valves per cylinder." In any case, once built, the locomotive ought to have been tried right out, if only for the boiler knowledge to be obtained from it.

It is easy enough to see why my father was able to do what he did, quite apart from his personal ability. He was applying his engine to an entirely new problem, and a problem that was being handled by young, active, and enthusiastic men with no past history to hold them back. These men cared nothing for accepted practice because, in the electrical industry at that time, there was no accepted practice. My father had been at war with accepted practice from his early days; consequently, both parties thought as one. Progress was rapid and has continued so ever since. Before the days of electric-lighting engines, my father and his partner, Mark Robinson, went into yacht and launch building because that was the simplest way to make the marine industry aware of the fact that engines could, and would, run with their working parts encased.

I have often wondered what his impact on the marine steam-engine industry would have been, had electric lighting not obtruded itself at that time. I am equally certain that, had he turned his attention to locomotive construction, something would have happened; there is in existence a pencil drawing of one of his three-cylinder engines in place in a 2-4-0 locomotive.

I wonder, too, how much longer it would have been before the gas turbine began to be applied to power production had it not been for the uninhibited mentality of those who go up into the air in aircraft, and occupy their business in the open sky.

Yours faithfully,
KYRLE W. WILLANS.

Shattrick,
Broadway, Ilminster, Somerset.
March 17, 1948.

PROFESSIONAL SALARIES.

TO THE EDITOR OF ENGINEERING.

SIR,—Although I agree with your correspondent, Mr. H. W. Norris, whose letter appeared on page 184, *ante*, that salaries in the engineering profession generally have not kept pace with increases negotiated by the trade unions on behalf of craft workers, still less with the rise in the real cost of living, there appears to me to be rather more justification for your editorial comments on the "Charter" published by the Association of Scientific Workers than your correspondent would seem to admit. Advertisements of vacancies clearly show that the scientific profession, particularly among the younger members, does not even enjoy the small advances which generally obtain in engineering. The backward position of science continues, despite the efforts of the A.Sc.W., and thus I consider that, when you stated that ". . . the employer . . . pays an adequate salary if he wants the work carried out properly because he has to," your statement was not entirely untrue. If it were, then surely there would have been no rises in salaried remuneration at all.

Nevertheless, Mr. Norris pays just tribute to the success of the ordinary trade unions in safeguarding their members' livelihood, as compared with the (comparative) failure of unorganised individual efforts among professional people. The principle of organised negotiation is now so firmly established in industry and our national life that no professional man need fight shy of joining his appropriate association, because it is affiliated to the Trades Union Congress. Political interests and activities are not compulsory for trade-union members, although the present economic crisis clearly shows that politics and wage negotiations are related. Even the British Medical Association are demonstrating the "value" of organised protection.

I would like to point out also, that the A.Sc.W. is not the appropriate trade organisation for all professional engineers. The Association of Supervisory Staffs, Executives, and Technicians also has a "charter," and includes in its organisation special branches, such as the Executive Staffs Branch, to cater for managerial and technical personnel. Because professional salaries are affected by the wages and conditions of workers and supervisors generally, I agree with Mr. Norris that professional engineers should support their appropriate organisation by joining the membership and participating in the discussions on these matters in the branches devoted to their own professional grade.

Yours faithfully,
D. S. CHUBB.

66, Clarence-road,
Teddington, Middlesex.
March 16, 1948.

MISSING SCRAP.

TO THE EDITOR OF ENGINEERING.

SIR,—It has been asserted that the overall collection of steel turnings in this country amounts to about 200,000 tons, but that the total production of such scrap is in the region of 400,000 tons to 500,000 tons per annum. The surplus is alleged to be dumped in refuse pits, etc., because the scrap merchants are not interested in such light and bulky scrap, and because the producers are rather asked to pay for removal than to sell.

I am endeavouring to collate positive information of the position regarding (*a*) uncollected steel turnings, and (*b*) other neglected and uncollected iron and steel scrap. If you would be kind enough to grant me the courtesy of your columns to help in this study, this would be much appreciated. I wish to appeal to engineers who have experience of either (*a*) or (*b*), however small in volume, to write to me, at the address given herewith, giving an estimate of the weight concerned.

Yours truly,
W. GEOFFREYS.

10, Jamaica-street,
Glasgow, C.2.
March 19, 1948.

CONFERENCE ON SAFETY IN CIVIL AVIATION.—On page 55 *ante*, we gave particulars of a full-day discussion on "Safety in Civil Aviation," to be held in London under the auspices of the Royal Aeronautical Society, on April 3. The Society have now announced that, owing to unforeseen circumstances, the conference has had to be postponed.

THE LATE MR. P. C. CROFT.—We regret to record the death of Mr. P. C. Croft, which occurred at Broughton, Chester, on Wednesday, March 17. Mr. Croft was assistant chief engineer of Messrs. Brookhirst Switchgear, Limited, Chester, and had made a number of valuable contributions to the solution of problems connected with electric-motor control.

THE INSTITUTE OF METALS.

THE fortieth annual general meeting of the Institute of Metals was held at the Institution of Civil Engineers, London, on Tuesday, Wednesday, and Thursday, March 16, 17 and 18. The chair at the opening session, at 2.30 p.m. on the first day, was occupied by the President, Colonel P. G. J. Gueterbock, C.B., D.S.O., M.A.

METAL STRIP ROLLING.

The first contribution considered was by Dr. M. Cook and Mr. E. C. Larke, of Imperial Chemical Industries, Limited, Metals Division, Witton, Birmingham, and dealt with the "Calculation of Loads Involved in Metal Strip Rolling." When presenting the paper Dr. Cook stated that attention had been directed to developing a method of computing rolling loads which dispensed with the need for the individual determination of the influence of a number of factors, including roll-face distortion. The derivation of the method was based on the assumption that the magnitude of the pure work of rolling was independent of the number of passes used in effecting a given reduction in thickness, and the basic experimental data required consisted only of a few measured values of the rolling loads developed in rolling one material under a series of different sets of rolling conditions. From these data, rolling loads could be readily computed for practices involving any number of passes, or a sequence of reductions in thickness could be established for which a constant load was developed in each pass. Results calculated by this method could be directly checked against measured values, and comparisons which had been made between calculated values and those obtained experimentally on steel and copper, in the course of investigations carried out by Dr. Hugh Ford and his collaborators at the Sheffield station of the British Iron and Steel Research Association, showed good agreement over the range of reductions encountered in normal rolling-mill procedure.

The discussion was opened by Dr. Hugh Ford, who stated that the present paper was the last act in a co-operative effort of a kind which was extremely useful and productive in research work. The steel industry, the non-ferrous metals industry and the makers of rolling-mill plant had co-operated in providing the equipment with which the experiments had been carried out. They had also provided the funds for running the equipment. In turn, Dr. Cook had provided a large quantity of high-conductivity copper specially prepared for the rolling experiment. Finally, they (Dr. Ford and his co-workers) had carried out the tests and handed them over to Dr. Cook and Mr. Larke, so that they could examine them in relation to the method which they had devised. This method depended upon having available a few values of roll force. There were, however, few cases in which roll-force meters had been fitted to rolling mills, and, therefore, the method seemed to depend either on being able to fit such meters or on determining a few values of roll force in some other manner. Thus, it seemed necessary to come back to methods of calculation of roll force such as those postulated by von Karman, Trinks, Orowan and others. The authors' method could then be applied and rapid calculations and estimations made of any rolling schedule required. The final answer would be found, no doubt, in the judicious combination of many of these methods to give the engineer, as rapidly as possible, the particular information he desired to obtain.

A contribution by Mr. W. C. F. Hessenberg, read, in his absence, by Mr. D. R. Bland, stated that the authors were to be congratulated on neatly side-stepping the difficulties associated with friction and roll-flattening. They had made no mention of the effect of speed, however, and, at present, there did not appear to be any method of calculation which took this into account, although it was frequently too high to be ignored. In the authors' experiments, the speed of rolling was relatively low and it might well be that for higher speeds the method was equally applicable, so long as the speed was maintained constant. This point would seem to need further investigation before the method

could be more widely applied with confidence. In his own contribution to the discussion, Mr. Bland said that the authors had stated that the increase in kinetic energy of the material, associated with the difference in exit speed of the strip and the peripheral speed of the rolls, was negligible, and the values of these speeds, therefore, had been taken as identical. He agreed that the kinetic energy was negligible compared with the work of deformation, but, if the argument were valid, the kinetic energy between entry and exit would also be negligible and the same argument could be used to show that the entry speed of the strip was equal to the exit speed, which was far from being the case. The reason why this question had not given rise to error in the present investigation was that the exit speed of the strip was very nearly equal to the speed of the rolls.

Professor F. C. Thompson, who closed the discussion, stated that two striking features of the paper were its simplicity of treatment, and the ingenuity which had been used in developing the technique described. The remarkable accuracy with which the results of energy consumed in horse-power-hours per ton, fell on a smooth curve when plotted against reduction per cent., was a completely convincing justification for the assumption which the authors had made, that the work done in effecting a given deformation was independent of the manner in which that work had been carried out. This assumption was by no means self-evident, even in the case of a material such as copper, and it was even less so for a material such as steel. Another point of interest was the rather curious shape of the basic curves, in which the rolling load in tons, or, in some cases, the specific roll pressure in tons per square inch, had been plotted against the reduction per cent. The curves showed either a kink, an arrest, or even a definite dip. If the authors had any ideas, however tentative, on the reason for this, they would be of great interest. In his opinion, there was only one kind of rolling and this was always cold rolling. The apparent difference between cold and hot rolling had nothing to do with the rolling process itself, but was something which happened after the rolling was completed and the pressure of the rolls had been relaxed.

In a brief reply, Dr. Cook stated that Mr. Larke and he had not been concerned with the relative merits of the various formulæ for calculating rolling loads. They did suggest, however, that, as they stood, these formulæ could not be employed for computing rolling loads with any degree of even approximate accuracy. It would still remain, apparently, a matter of guesswork and of judgment to some extent, to obtain the particular values which were to be assigned for some of the factors in the formulæ. In answer to Mr. Hessenberg, they had not taken, and could not take, cognisance of the possible effect of speed of rolling, but, on the face of it, it did not appear that this would vitiate the method. There were other factors which had not been considered in their computations. One was the application of tension, either on the ingoing side or at the exit from the rolls. In reply to Professor Thompson's point, they had not been at all concerned with the metallurgical aspects and he was not prepared, at short notice, to expound any theory which might help to explain the shape of some of their basic curves.

Ternary Aluminium-Rich Alloys.

The next two papers on the agenda were presented in turn and then jointly discussed; they were both communications from the School of Industrial Metallurgy, University of Birmingham. The first was entitled "Hot-Shortness of Some High-Purity Alloys in the Systems Aluminium-Copper-Silicon and Aluminium-Magnesium-Silicon," and was by Dr. P. H. Jennings, Dr. A. R. E. Singer and Mr. W. I. Pumphrey; and the second bore the title, "A Consideration of the Constitution of Aluminium-Iron-Silicon Alloys and its Relation to Cracking Above the Solidus." The authors were Dr. P. H. Jennings and Mr. W. I. Pumphrey. When presenting the first paper, Dr. Jennings stated that the methods of investigating hot-shortness previously employed for aluminium-silicon and aluminium-iron-silicon alloys, namely, the carrying out of a ring-casting test and a restrained-weld test, had been applied to the system aluminium-copper silicon and aluminium-magnesium-silicon. The results had enabled ternary hot-shortness diagrams to be constructed for both systems, from which a knowledge could be gained of the relative welding and casting behaviour of alloys in the ranges: copper 0 to 10 per cent. and silicon 0 to 4 per cent.; and magnesium 0 to 10 per cent. and silicon 0 to 5 per cent. The hot-shortness of binary and ternary alloys appeared to depend upon the extent of the hot-short temperature range, namely, that range in which the alloys possessed appreciable strength but no elongation. This, in turn, was a function of the freezing range and the proportion of liquid freezing at a constant temperature. In ternary systems, however, other factors, such as the temperature at which secondary separation began, might be of importance. The application of the original theory of hot-shortness to aluminium-magnesium-silicon alloys was complicated by the presence of the magnesium-silicide phase.

When presenting the second paper on the constitution of aluminium-iron-silicon alloys, Dr. Jennings stated that the relationship between the constitution and the susceptibility to cracking of aluminium-rich aluminium-iron-silicon alloys appeared to be similar to that suggested for binary aluminium-silicon alloys. This relationship, however, was less easily established in the ternary system because of the uncertainty regarding particular features of the constitutional diagram. The small tendency to cracking of alloys in which there was a preponderance of iron over silicon was due to the fact that, as the iron content increased, the ternary-eutectic arrest at 577 deg. C. diminished in magnitude and became unobservable at an iron: silicon ratio of about 1 : 1. The major portion of the solidification was thus completed at about 615 deg. C., and there was an effective shortening of the liquidus-solidus interval.

The discussion was opened by Dr. E. G. West, who stated that the researches which were being carried out by the team at Birmingham had as their objective the improvement of the welding of existing alloys, with the possibility of developing new alloys of better weldability and more satisfactory properties in other respects. It was likely that the results obtained so far on the aluminium-magnesium-silicon series would be found to have some immediate bearing on the welding of these alloys, which, of course, were widely used in compositions up to about 1·5 per cent. magnesium and silicon. There were quite important variations in the basic compositions of these alloys in commercial use, all covered at present by one rather "omnibus" specification; and it might very well be that the researches had already progressed sufficiently far for the manufacturers and users of these alloys to make some choice as to the exact composition which would give them greater freedom from the risk of cracking. The effects of other elements, of course, must be taken into account—the impurity iron and the additions, chromium and copper, for example—and it was to be hoped that the investigators would venture into these quaternary and even higher fields. The work on the aluminium-copper-silicon alloys had largely confirmed the results of the work already reported by the British Non-Ferrous Metals Research Association some two years previously on alloys of the DTD No. 24 type, produced in both cast and wrought forms.

Mr. R. Chadwick thought that the authors could have laid greater emphasis on the importance of the question of hot-shortness and the long freezing range. He added that it was not just in welding that a long freezing range gave rise to trouble; it was met with in casting, in hot rolling, extrusion, forging and all kinds of hot manipulation. Lees, in a paper published in 1946, had referred to "hot-tearing" in castings and, in the present paper, it might have been preferable to employ the same term. Something should be done to try to establish uniformity in nomenclature in dealing with a subject such as casting. It was interesting to observe that the authors had arrived at a conclusion similar to that recorded by the British Non-Ferrous Metals Research Association, regarding an aluminium-copper-silicon alloy suitable for welding, namely, one containing copper and silicon in which the silicon was roughly twice the copper content. The next speaker, Major P. C. Varley stated that some of the anomalous results found by the authors might be explained by the presence of variable amounts of gas dissolved in the metal or by the inevitable introduction of a small quantity of sodium from the flux used in the melting operation. Work by Lees had shown that gas content could have an effect on hot-shortness while sodium had long been held to be responsible for poor ductility at high temperatures in alloys of the Duralumin types.

Mr. R. W. Ruddle voiced doubts on the validity of the ring-casting tests employed by the authors. He said that a test which, as was stated, it had been necessary to reproduce 16 times on occasion, and in which variations in the length of cracking of up to 30 per cent. occurred, could scarcely be regarded as satisfactory. The severity of cracking was extremely difficult to judge, and from the practical point of view what was important was whether the casting or weld cracked at all, and he reaffirmed his conviction that any test of hot-shortness should be of the "crack or no-crack" variety. The general picture afforded by the authors' tests, he believed, was qualitatively correct, but some caution was needed. In particular, some alloys which, according to the test results, were not hot-short might, in fact, have some tendency in this direction.

Mr. E. A. G. Liddiard stated that his co-workers and he had done a certain amount of work using the ring test, together with other tests, to assess casting characteristics. The reproducibility of their results, however, had not been as good as that obtained by the authors. The next speaker, Mr. W. A. Baker, said that, like an earlier speaker, he had some misgivings concerning the ring-test casting. Although it had obvious advantages he suggested that the better way to assess casting characteristics was to vary the degree of restraint on the material while it was solidifying, and then to see whether or not it cracked. He agreed that the real criterion was "crack or no crack." On the other hand, results obtained by the British Non-Ferrous Metals Research Association, on alloys of commercial purity, agreed very well indeed with the results in high-purity aluminium-silicon-copper alloys obtained by the authors. Incidentally, the welding behaviour of the alloys, containing about 3 per cent. of copper and from 4 to 6 per cent. of silicon, were thought to be so favourable that the Association had patented them for that application. The last speaker, Dr. E. Scheuer, said that he considered the ring-casting test to be very important. It might be less sensitive than other tests, but it had one advantage; it gave a figure and this could be plotted against composition. It might be that, if more work were done on it, it could be made so reliable and certain that it would become a routine test.

Dr. P. H. Jennings, in reply, said, in answer to Mr. Chadwick, that the freezing range was by no means the same as that which they had called the hot-short-temperature range, and the proportion of eutectic present was an important factor in the relations between these two temperature ranges. He agreed that there was considerable confusion and lack of precision in the nomenclature now used, and an endeavour would be made in future papers to clarify matters in connection with the terms "hot-shortness," "hot-tearing" and "hot-short temperature range." In answer to Major Varley, they had carefully standardised their experimental conditions and he could not imagine that the introduction of gas could have played any part in influencing their results. Moreover, analyses of the original aluminium-silicon alloys had shown the sodium content introduced from the flux to be negligible. A "crack or no crack" type of test involved a lengthy experimental procedure and several different moulds, and Dr. Scheuer's remark that the ring-casting test did give a figure, was an important feature in its favour. They had found it to be necessary to standardise testing procedure very carefully in order to obtain reproducible results. This applied particularly to the casting temperature, which was standardised at 100 deg. C., above the liquidus, and a departure of 10 deg. from this temperature, might substantially influence the results.

(To be continued.)

THE INSTITUTION OF NAVAL ARCHITECTS.

(*Continued from page* 281.)

IN last week's issue of ENGINEERING we reported the opening, on March 17, of the 1948 Spring Meeting of the Institution of Naval Architects, which was held in the lecture theatre of the Royal United Service Institution, Whitehall, London, S.W.1. The proceedings on the morning of the first day of the three-days meeting included the induction by the retiring President, Admiral of the Fleet Lord Chatfield, of his successor, Admiral of the Fleet Viscount Cunningham of Hyndhope, whose address we reprinted with some slight abridgments. Lord Cunningham then called on Mr. W. MacGillivray to read the first of the nine papers in the programme of the meeting, which was entitled, "Speed at Sea and Despatch in Port."

SPEED AT SEA AND DESPATCH IN PORT.

MR. MACGILLIVRAY'S paper was a discussion, from the shipowner's point of view, of the economics of ship operation in the light of the modern tendency towards increased speed at sea of both liners and tramp ships—to be achieved only at the cost of considerably greater capital outlay, a heavier consumption of fuel, and higher running costs—and the concurrent decline in the speed of port operations, which largely nullifies the advantages gained from the increased sea speed. The paper discussed the economics of the various types of propelling and auxiliary machinery, comparing the time spent at sea with that spent in port, and analysing the operating costs over a period of years; this analysis showed that the heaviest item in a shipowner's operating expenses was usually the cost of handling cargo. The author indicated that considerable economies could be effected by improvements in the equipment and organisation of ports, and advocated the employment of labour in two shifts of eight hours each rather than in one shift with overtime. He formed the general conclusion that the full benefit of higher speed at sea could be attained only by reducing the turn-round time in port and urged that much more attention than hitherto should be given to the problems of cargo handling, both on board ship and on shore. Included in the paper was a description of a method of cargo-handling and stowage known as "palletisation," which was stated to be in successful use by Canada Steamship Lines in their Great Lakes ships. It is applicable more especially to bagged, baled or cased goods, which can be stacked on pallets or trays and transferred from shore to ship or vice versa on lifting trucks. The author also showed a film, illustrating the highly mechanised "Ship and Shore" system invented by Mr. Charles Ellis, of New York, in which trays of package cargo are moved on flat trucks, drawn along rails on the quay and in the ship by conveyor chains, and placed in the hold by an elevator.

Mr. J. B. Crawford, B.Sc., who opened the discussion, said that the author had remarked on the old-fashioned "main hold"; generally, this was No. 2 hold. The main hold was something of a menace, for, obviously, if it were flooded, there was the likelihood of losing the ship. A hold 60 or 70 ft in length, with a hatch, say, 50 ft. long, seemed reasonable. Was there any cargo that would justify a longer hold?

Mr. R. C. Thompson, C.B.E., B.A., commenting on the section of the paper dealing with steam and electric auxiliaries, said that no account seemed to be taken of the fact that the vessel with electrical auxiliaries, which consumed 4,000 tons less oil than the ship with steam auxiliaries in the period quoted, might have earned freight on 4,000 tons of extra cargo; alternatively, a ship of smaller deadweight, with electrical auxiliaries, could have done the same work as the larger ship with steam auxiliaries, with consequent saving of costs. He did not think the comparison was a fair one without taking that into account. If the average sea speed of ships were greater now than pre-war, and if the time of loading and discharging were the same, then the post-war faster ships would spend a greater number of days in port per annum. He did not suggest that that was the whole explanation of the present excessive time spent in port, but it should not be ignored.

In the sections dealing with port equipment and organisation and with ships' winches and derricks, the author cited three vessels which regularly handled 14,000 tons of general cargo in three days. Mr. Thompson emphasised that it was all handled by the ships' derricks and winches, without assistance from dock cranes; so it did not appear that there was anything wrong with a well-designed set of ship's derrick and winch gear. If such gear were not used to its full capacity, that was the fault of those who used it, or of the organisation and facilities for getting the cargo to or from a position where it could be handled by the ship's gear. He understood that there were still port authorities in this country who would not allow ships' gear to be used. It had been proved that one man could work two electric winches operating union derrick gear, with suitable grouped central control, 40 per cent. faster than two men could operate the same gear with individual control, but that such a labour- and time-saving practice was not allowed in many ports. Further, he understood that, even if the winch controls of electric winches were arranged so that the winch operator could see down the hatch, and therefore, did not require a signalman, in this country a signalman still had to be employed. Shipbuilders learned about such things largely because they were building ships for foreign owners, who were very keen on the arrangement of twin winches operated by one man; and certain trades, covering certain ports, could make good use of that facility. Therefore, Mr. Thompson suggested, it was time that shipowners generally took a more active part in tackling the restrictive practices in the various ports, where the rules and regulations prevented the best cargo-handling arrangements being used to proper advantage.

Sir Amos Ayre, K.B.E., drew attention to the statement that, in the construction of post-war merchant ships, there was a growing tendency towards greater speed at sea, only to be achieved by considerable extra capital outlay, heavier fuel consumption and increased running costs. There was also the refreshing admission by a shipowner that part of the increased cost was due to shipowners now requiring all sorts of refinements in crew accommodation, ventilation, lifeboats and fire detection apparatus, etc.; electrical auxiliaries, for instance, might add 25,000*l.* or 30,000*l.* to the total cost. As showing how much more the shipbuilders were putting into ships to-day, Sir Amos said that the present-day requirements and recommendations of the Ministry of Transport, as compared with those of 1938-39, might involve the expenditure of another 15,000*l.* or 20,000*l.*

Extra speed must be paid for; and he believed that, in the average case, about 25 to 33 per cent. more horse-power was being put into ships than before the war. The whole list of extras, in a ship of about 10,000 tons deadweight of the cargo liner class, probably introduced 400 tons of extra weight; then, for the higher speed, the lines would be finer, and the size of the ship had to be increased to regain the deadweight thus lost. In comparing costs, all these important factors had to be borne in mind; he believed that a ship to-day was about 25 to 35 per cent. more costly on the same price basis. The author's suggestion of a pontoon equipped with mobile cranes, to enable lighters to be operated between ship and quay, was the kind of provision made during the war for dealing with vessels for Murmansk and Archangel. He had often wondered why cranes were not more widely used in ships, but the ordinary derrick was apparently very efficient, and it might be cheaper.

Mr. MacGillivray, replying to Mr. Crawford, said that, for awkward cargoes, such as steam pipes 60 ft. long, it was necessary to have one fairly long hold. It was surprising to note, however, that only the up-to-date cargo liners seemed to be double-rigged at the long hold. All the Liberty ships built during the war were only single-rigged at the hold, and quite a number of the British merchant ships of 10,000 tons, built during the war, were also single-rigged. In small ships, No. 2 hold was now about twice the size of the other two, and it was double-rigged, giving much better discharge. Theoretically, all the holds should finish discharging or loading at the same time. Mr. Thompson had spoken of the freight that was shut out of a ship using steam for winches and auxiliaries rather than electricity; but, in the liner trade, it was not the general custom to load a ship down to her marks. The three vessels which handled 14,000 tons of general cargo in three days were cited as indicating what could be done before the war; he did not think it was possible now, because the labour could not be obtained. Shipowners should do, and were doing, what they could to stop restrictive practices at ports. Only on the previous day, Mr. MacGillivray had been told that, at a certain British port, two men in every gang on the ship and on the quay took a spell of an hour at a time for coffee or a smoke; out of a gang, there were two men doing nothing throughout the day.

The Maltese Prince, the latest ship built for the Prince Line by the Burntisland Shipbuilding Company, carried Palestine oranges. In that trade, it was not usual to provide refrigeration, the fruit being carried in ordinary holds with fan ventilation. In that ship, however, it was decided to use a small machine to supply cold air; but not to provide insulation, which was the great item of cost in refrigeration. Instead of having wastage of 10 to 20 per cent. at this time of the year, when the ship discharged her last cargo the wastage was only one-seventh of one per cent.; the cargo was practically perfect. The cost was about 15,000*l.*, instead of something like 150,000*l.* for a fully refrigerated ship. The other alternative would have been to build a much faster ship, as the Scandinavians were doing; instead of 13-knot ships, they were running 15 or 16-knot ships, costing 100,000*l.* or 150,000*l.* more. It was proved that the fruit was being carried much better in a ship with refrigerating machinery costing 15,000*l.* than in the Scandinavian ships costing 150,000*l.* extra. The fruit was taken on board in Palestine under conditions of high temperature—on the last voyage, it was 75 deg. to 80 deg. F.—but within two or three days the temperature was down to 40 deg. F. and it was maintained at that level throughout the voyage.

THE INSTITUTION DINNER.

On the evening of March 17, the annual dinner of the Institution was held at the Connaught Rooms, London, W.C.2, the chair being taken by the newly-elected President, who proposed the toast of "The Guests." In the course of his remarks, Lord Cunningham expressed the view that the use and control of the sea would continue to be of vital importance to Britain, probably for several generations still to come; and that, while ships might have to face attack by atom bombs, they would certainly have to deal with attacks by submarines of unprecedented submerged speed. Of the two, he regarded the latter as the greater menace to shipping. Fleets would have to be able to remain at sea almost indefinitely and, therefore, would require a service of specially-designed auxiliary vessels to supply them. He coupled with the toast the name of Air Chief Marshal Sir Frederick Bowhill, G.B.E., K.C.B., Master of the Honourable Company of Master Mariners, who, referring to the influence of the sea on civilisation, pointed out that Europe had a mile of coast to 114 square miles of land area, whereas, in Asia and Africa, the ratios were 1:490 and 1:700, respectively. He did not think that air transport would have an adverse effect on the older forms of transportation. The Rt. Hon. J. A. Beasley, Resident Minister for the Commonwealth of Australia, proposed the toast of "The Institution," to which Sir Charles Lillicrap, K.C.B., vice-president, responded. Since the days when the screw was an auxiliary to sail, said Sir Charles, the Institution had fostered scientific and engineering thought. Now it was faced with revolutionary developments in the methods of waging war and harnessing atomic energy to peaceful purposes, not the least of which would be the propulsion of ships. In the next decade or two, the industry would be again at a cross-roads and it would be the duty of the Institution once more to point the way in which development could best be concentrated and effort directed.

The annual dinner is so important an event, as a means of enabling members—some of whom have

few other opportunities—to renew old acquaintanceships and to make new ones, that we must regret the decision of the Council not to provide for each diner the customary printed seating plan and list of the names of those present. The reason, we understand, was the high cost of printing; but we feel that it was a misplaced economy and that many members would rather pay an increased charge for the ticket than be deprived of this means of locating friends quickly in a crowded hall.

(To be continued.)

STANDARDISATION OF SWITCHGEAR.*

By D. E. LAMBERT and J. CHRISTIE.

(Concluded from page 283.)

FOR 66-kV indoor service, where the fault MVA is 1,000 to 2,500, metal-clad switchgear with bulk oil-volume or small oil-volume circuit breakers has been installed and experience with it has been good. Open-type small oil-volume or air-blast circuit breakers suitably arranged as an indoor layout are an attractive alternative, the advantages being that standard units of circuit breakers, current transformers, voltage transformers and isolators can be arranged to suit the user's particular requirements and conditions. With metal-clad switchgear each design has a limited application and metal-clad air-blast circuit breakers for this voltage are very costly. Standard open-type outdoor switchgear with very slight modification, if any, can generally be used. For 132-kV indoor applications, metal-clad switchgear of any kind does not appear to be suitable at present; and here again open-type small oil-volume and air-blast circuit breakers seem to be the obvious solution. Many types and designs of indoor switchgear for 22/33 kV, where the fault MVA is 1,000 to 1,500, are in use. The requirements that have to be met by generating station metal-clad switchgear at these voltages are diverse, but the solution of the standardisation problem would appear to be double 'bus-bars with compound and/or oil-filled switchgear and plug selection; or a transfer or fixed circuit breaker with internal isolation. The single 'bus-bar arrangement obviously affords the simplest solution, but double 'bus-bars are frequently required. For transmission and distribution stations metal-clad switchgear with single or double 'bus-bars has proved satisfactory and could be standardised. Metal-clad and metal-enclosed switchgear with oil or air-blast circuit breakers and open type switchgear with small oil-volume or air-blast circuit breakers are available for indoor distribution stations operating at 6·6/33 kV, where the fault MVA is 250 to 750. The metal-clad oil circuit breaker is preferable for these purposes owing to its compactness, insulation security and reliability. There are a large number of combinations of voltages, breaking capacities and current ratings in this range and standardisation is further complicated by the wide variety of designs. A sound standard would, however, provide for compound-filled double 'bus-bars with off-load 'bus-bar selection, plugs or transfer circuit breakers; a two-break circuit breaker with arc-control devices; horizontal or vertical isolation and solenoid or spring operation with motor recharging when required.

The requirements for indoor switchgear for 3·3/11-kV distribution stations, station auxiliaries and industrial use, where the fault MVA is 75 to 150, are essentially different from those already given because large numbers of units are involved and low cost consistent with sound design is a prime consideration. At 3·3/6·6 kV, and possibly at 11 kV, the air-break circuit breaker will probably eventually show itself to be the best for standardisation, but there has not been enough experience in Great Britain to indicate the lines on which this standardisation should proceed. There will, however, still be a demand for the oil circuit breaker, particularly at 11 kV, owing to its compactness and freedom from trouble due to condensation in humid atmospheres. It is, therefore, suggested that it should be considered for standardisation. The following features might be adopted as standard to meet the main demands for this range of switchgear: single 'bus-bar with compound or air insulation; vertical isolation; hand or spring closing, and two-break circuit breaker, with or without arc control. Its components should also be utilisable for a wide variety of combinations to meet growing needs, and it should be rendered suitable for adaptation to ring-main distribution, by the addition of isolators.

The types and sizes of switchgear for indoor industrial use at 400 to 3,300 volts can best be considered under four headings. The demand is considerable, the requirements are fairly well stabilised and standard units could be developed for quantity production. For 3,300 volts and below, oil circuit breakers and horizontal draw-out pattern switchgear is almost universal. The non-flameproof type generally takes the form of a two-break circuit-breaker with series trip coils, transformers and earth-leakage protection and with under-voltage releases, when required, in motor circuits. The 'bus-bars can be with or without compound filling and facilities should be provided for mounting instruments and a voltage transformer. In view of its small bulk and its low cost, this switchgear is unlikely to be superseded for some time. The range of 400 to 600 volt oil circuit breakers for generating-station auxiliaries and industrial use, where the fault MVA does not exceed 50, has in the past consisted of metal-clad two-break horizontal draw-out circuit-breakers with air-insulated metal-cased 'bus-bars. This switchgear has hand or solenoid closing, special provision being made with the former for the inclusion of a making-current release owing to the difficulty of closing fully home against any large short-circuit forces. Switchgear of this type is being rapidly superseded by air-break circuit breakers, several patterns of which have been produced. From the point of view of standardisation, this comparatively new development offers a possible field for consideration by manufacturers interested in the rationalisation of dimensions and components. Air-break switchgear, where the fault MVA does not exceed 25, is used mainly for low-voltage distribution with current ratings up to 1,000 amperes and usually takes the form of built-up units. Short-circuit protection is generally obtained by employing cartridge fuses and some standardisation, even of dimensions, could usefully be undertaken.

Pole-mounted circuit breakers are used extensively for 11-kV overhead rural distribution with breaking capacities up to 100 MVA and with a normal current rating of 200 amperes. In Great Britain these circuit-breakers are generally three-phase with inverse time-lag series over-current protection, including oil dash pots or a mechanical chain of wheels; or with current transformer-operated over-current and earth-leakage protection. In addition, a mechanism for automatic reclosing operated by a falling weight or by a battery of springs is fitted to avoid interruptions due to transient faults. Before standardisation is undertaken guidance is, however, required from the supply authorities on the use of three-phase as against single-phase and on the level of insulation required. Economical standard units for teeing off cables for remote supplies are necessary. The two main classes of this kind of equipment are switch-fuses and isolators. Two distinct types of the former are available, in one of which the cable is taken out at the side or bottom; and there is a lid so arranged that it can be raised for access to the fuses. In the other, the cables are taken out at the side and access to the fuses is obtained by lowering the tank. Both types have advantages, but there seems no reason why a standard arrangement based on either could not be adopted. There are two fundamental types of isolators. In one of these, two double-break oil-immersed isolators are connected in series. A tee-off is taken from the connections between them and may go straight to a cable box or switch-fuse, combined with the isolator unit, or through a 'bus-bar to switch-fuses or circuit breakers. The disadvantage of this is that maintenance is only possible when the ring main is dead and earthed on both sides of the tee-off and the tee-off itself is dead. The other arrangement is similar, except that there are separate tanks and plugs for isolation and earthing. Either isolator can therefore be made dead in turn for maintenance and inspection, while the tee-off is alive from the other side. Similar facilities are available for testing one side of the ring main without interrupting the supply to the tee-point. These advantages, however, are obtained only at increased cost. Each type has its particular application, and before any standardisation is considered the whole position should be reviewed to ascertain users' requirements.

Before any standardisation or rationalisation of mining switchgear is decided upon, a lead is required from the controlling authority on the methods likely to be most commonly used in future, and on the technical requirements. Two classes of switchgear are involved: that for the medium-voltage system near the coal face (400/660 volts), and that for the main distribution (3,300/6,600 volts). The technical requirements of the former are influenced largely by the method of working. This determines the size and voltage of the transportable distribution stations, the length of the conveyors and the size of the coal-cutting equipment which, together with the switchgear, will normally be used in the area within 300 yards of the coal face. Protection and control introduce problems peculiar to mining switchgear and many arrangements have been developed particularly in relation to intrinsic safety. Recent indications are that some of these features introduce complications without adequate return in additional safety and involve more maintenance. Oil-immersed draw-out switchgear has in the past satisfied the limited flameproof requirements met with throughout a mine. To-day, however, to meet the requirements of B.S. 229 for switchgear operating within 300 yards of the coal face, the construction of oil-immersed flameproof switchgear becomes complicated and expensive. The most economical way to meet these requirements is to install medium-voltage air-break switchgear within the 300 yards limit or in other positions where the gas concentration exceeds the specified value. Elsewhere, standard switchgear of the non-flameproof mining type with oil-breaks can be used with confidence. If this is accepted, the most economical range of switchgear could be evolved.

The design and arrangement of many of the component parts of switchgear are more or less stabilised and could be standardised. For instance, one manufacturer has reduced a range of 54 types and sizes of cable gland to six sizes, all of one type. It would also appear that a series of standard types and sizes for the isolators used with open-type switchgear could be designed for quantity production. Early standardisation of auxiliary equipment should also lead to a diminution of varieties and promote quantity production. On the other hand, the technical requirements specified for current transformers are so diverse that standardisation of their construction is only possible to a limited extent.

The authors suggest that to achieve quicker consideration of the kind of problems and proposals set out in the paper a small technical "Provisional Standards Panel" should be set up consisting of users, consulting engineers and manufacturers, which would review technical progress and requirements in relation to ratings and performance and issue recommendations and provisional standards for the guidance of industry. This would make it possible to consider the design of standard switchgear to meet standard requirements. For this purpose, it is suggested that a "Design and Utilisation Panel" should be appointed to put the recommendations and provisional standards of the Provisional Standards Panel into practice.

To sum up, switchgear design and development as a whole are not as yet stable enough to allow standardisation of construction to be undertaken to any great extent. This is attributable partly to the diverse requirements and partly to the progressive development of the circuit breaker and its associated components. Greater standardisation could be achieved by reducing the variety of requirements, in relation to ratings, system conditions, special features and non-standard performance. The progressive development of switchgear and, in particular, of circuit-breakers and circuit-breaker technique involves an almost continuous review of the appropriate standard specifications. The incorporation in these of many of the performance requirements necessarily lags far behind the development and to assist standardisation of switchgear generally it is considered that some recommendations and provisional standards should be prepared and used by manufacturers until British Standards are available. The degree of standardisation of types and constructions of switchgear possible at present is dependent on the voltage and application. At the lower voltages, standardisation of complete units appears to be feasible and would result in achieving one of the main objects of that practice, namely, improved manufacturing efficiency. At the higher voltages, where types and construction are less stabilised, little standardisation is possible. For very high voltage switchgear the cost of research, development and testing plant in relation to the total demand appears to warrant a measure of rationalisation, including communal research and testing facilities. The design and construction of many switchgear components and much auxiliary equipment are fairly well stabilised and should be standardised.

* Paper read before the Institution of Electrical Engineers on Thursday, January 15, 1948. Abridged.

THE LATE MR. E. J. FOURACRE.—We note with regret the death of Mr. Edgar J. Fouracre, which occurred at his home in Ealing, London, W.5, on March 10. Mr. Fouracre, who was 61 years of age, was a director and general sales manager of Westinghouse Brake and Signal Company, Limited, and had completed nearly 48 years of service with that company. He was educated at Chippenham Grammar School, Wiltshire, and, in 1900, joined the firm of Messrs. Evans and O'Donnell, at Chippenham, then engaged in manufacturing mechanical signalling equipment. He was transferred to Saxby and Farmer, Limited, Kilburn, in 1903, and, on the amalgamation of the two companies was removed to the head office of Saxby and Farmer, Limited, Victoria-street, London. At the next amalgamation, that of Saxby and Farmer, Limited; McKenzie, Holland and Westinghouse Power Signal Company, Limited; and Westinghouse Brake Company; Limited, in 1921, Mr. Fouracre was made assistant sales manager. In 1932, he became sales manager, and in 1946, director and general sales manager. He was also a director of the Railway Signal Company, Limited, Liverpool, and deputy chairman of the Railway Brakes and Signals Industrial and Export Groups.

LAUNCHES AND TRIAL TRIPS.

M.S. "GANDA."—Single-screw cargo vessel, with accommodation for twelve passengers, built by the Burntisland Shipbuilding Company, Limited, Burntisland, Fife, for the Companhia Colonial de Navegaçao, Lisbon. Main dimensions: 442 ft. by 59 ft. by 38 ft. to shelter deck; deadweight capacity, 9,270 tons on a draught of 25 ft. 11½ in. Four-cylinder opposed-piston Doxford Diesel engine of 4,400 brake horse-power, giving a speed on trial of 15 knots. Trial trip, February 25.

M.S. "BRITISH SECURITY."—Single-screw oil tanker, built and engined by Messrs. Harland and Wolff, Limited, Queen's Island, Belfast, for the British Tanker Company, Limited, Finsbury-circus, London, E.C.2. Main dimensions: 463 ft. by 61 ft. 6 in. by 34 ft.; deadweight capacity, about 12,280 tons on a draught of 27 ft. 6 in. Harland-B. and W. six-cylinder four-cycle Diesel engine, of approximately 3,200 brake horse-power, and giving a speed of about 11¼ knots. Launch, February 27.

S.S. "SPICA."—Single-screw cargo vessel, built and engined by Messrs. Smith's Dock Company, Limited, South Bank-on-Tees, to the order of Rederiaktiebolaget "Iris," Stockholm. Main dimensions: 300 ft. by 46 ft. 7 in. by 28 ft. 3 in. to shelter deck; deadweight capacity, about 3,600 tons on a draught of 19 ft. Triple-expansion surface-condensing type steam engines, developing 1,700 indicated horse-power, with a speed of about 12¼ knots. Launch, March 11.

M.S. "WESTBANK."—Single-screw cargo vessel for the carriage of fruit, vegetable or fuel oils, and latex, built and engined by Messrs. William Doxford and Sons, Limited, Pallion, Sunderland, for the Bank Line, Limited (Messrs. Andrew Weir and Company), Bury-street, London, E.C.3. Main dimensions: 464 ft. 3 in. by 60 ft. by 29 ft. 3 in.; deadweight capacity, about 9,100 tons. Doxford five-cylinder opposed-piston oil engine giving a service speed of 14 knots. Launch, March 11.

S.S. "SNAEFELL."—Twin-screw vessel with accommodation for 2,300 first and third class passengers, built and engined by Messrs. Cammell Laird and Company, Limited, Birkenhead, for The Isle of Man Steam Packet Company, Limited, Douglas. Main dimensions: 344 ft. 3 in. by 47 ft. by 26 ft. to shelter deck; gross tonnage, approximately 2,500. Two sets of Parsons turbines, with double-helical single-reduction gearing, to provide a speed of 21 knots. Launch, March 11.

M.S. "RAJAH BROOKE."—Twin-screw cargo vessel, with accommodation for forty first class passengers, together with native passengers carried on decks and in 'tween decks. Built by the Caledon Shipbuilding and Engineering Company, Limited, Caledon Shipyard, Dundee, for the Sarawak Steamship Company, associated with the Singapore Straits Steamship Company, Singapore. Main dimensions: 250 ft. by 47 ft. 6 in. by 26 ft. 3 in. to shelter deck; deadweight capacity, 1,990 tons. Two six-cylinder two-stroke single-acting Diesel engines, of 1,920 aggregate brake horse-power, supplied by Messrs. Atlas Diesel Company, Limited, Beresford-avenue, Wembley, Middlesex, to provide a speed of 13 knots. Trial trip, March 15.

M.S. "HERTFORD."—Twin-screw refrigerated cargo vessel built by Messrs. Vickers-Armstrongs Limited, Naval Yard, High Walker, Newcastle-upon-Tyne, 6, for the Federal Steam Navigation Company, Limited, 138, Leadenhall-street, London, E.C.3. Main dimensions: 530 ft. by 70 ft. by 39 ft. to main deck; deadweight capacity, about 14,000 tons on a draught of 32 ft. 6 in. Two five-cylinder opposed-piston Vickers-Doxford oil engines developing a total of 12,800 brake horse-power, with a speed of 17 knots. Launch, March 24.

LYMINGTON-YARMOUTH FERRY: ERRATUM.—We regret that in our issue of March 12, on page 245 *ante*, an incorrect name for the new Lymington-Yarmouth ferry was given. The correct name of the vessel is the M.S. Farringford—after Tennyson's famous home near Freshwater Bay.

LOCOMOTIVE EXCHANGES.—An exchange of passenger, mixed-traffic and freight locomotives, is being arranged by the Railway Executive between the regions of British Railways, with the object of obtaining data on which to base plans for future standardisation of locomotive designs. Dynamometer cars will be attached to all trains hauled by the exchanged engines, the locomotives will use the same grade of coal when working on the same test, and they will be manned by the crews who normally work them in their home regions. The types of locomotives to be tested are: L.M.S. "Duchess" 4-6-2, "Royal Scot" 4-6-0, Class 5 4-6-0, Class 8 2-8-0; L.N.E.R. A4 4-6-2, B1 4-6-0, O1 2-8-0; G.W.R. "King" 4-6-0, "Hall" 4-6-0, 38XX 2-8-0; S.R. "Merchant Navy" 4-6-2, "West Country" 4-6-2; and the War Department "Austerity" 2-8-0 and 2-10-0 locomotives. The tests will commence on Monday, April 19, and will be completed in about four months. Routes have been chosen in England, Scotland and Wales.

LABOUR NOTES.

REVIEWING the White Paper dealing with the subjects of wages, prices, and profits, the writer of the "Notes and Comments" in *Man and Metal*, the journal of the Iron and Steel Trades Confederation, submits that "it must be understood that where claims for increased wages are based upon increased output, these claims must be admitted." "To deny such claims," he writes, "would be to destroy all incentive, and would invite defeat of the very objects outlined in the White Paper." "Nor," he goes on, "must it be forgotten that there are tens of thousands of workers whose wages, even now, condemn them and their families to a level of subsistence which is far too low, and no obstacle must be placed in the way of the unions whose constant endeavour it is to raise the wages of these lower-paid workpeople to a more reasonable standard."

"Then there are," the writer continues, "the undermanned essential industries, to which the attraction of sufficient manpower is a matter of the first importance. Anyone who imagines for one moment that the average worker would willingly give up a non-essential but well-paid job for a more essential but not so well-paid job, is in need of the services of a psychiatrist. It is in the national interest, therefore—and this seems to be appreciated by the Government—that standards of wages and conditions should be established in the industries regarded as essential to the national economy which would be calculated to attract the necessary labour."

"The General Council of the Trades Union Congress insists," he says, "that recognition must also be given to the need to safeguard certain wage differentials which are an essential part of the wages structure of many important industries, and are necessary to encourage those standards of craftsmanship, training, and experience essential to the maintenance of a high level of efficiency and maximum production. A definite assurance from the Government that these principles will receive complete recognition, coupled with a policy, firm and vigorous in its application, designed to reduce prices and profits, are pre-requisites to the endorsement of the White Paper by the Trade Union Movement."

Sitting at Geneva, the United Nations Maritime Conference adopted for signature and acceptance by the Governments, a convention setting up an intergovernmental maritime consultative organisation to deal with all maritime questions, and to act as one of the specialised agencies of the United Nations. The conference was attended by representatives of 32 Governments, and the convention was adopted by 18 votes to 1, with 13 abstentions. China voted against it on the ground that further study of the matter was required.

The eighteen nations which voted in favour of the adoption of the convention were Argentina, Australia, Belgium, Canada, Colombia, Finland, France, Greece, India, Eire, Italy, the Netherlands, Poland, Portugal, Switzerland, Britain and the United States. The representatives of the following Governments abstained—Brazil, Chile, Czechoslovakia, Denmark, the Dominican Republic, Egypt, the Lebanon, Norway, New Zealand, Pakistan, Panama, Peru, and Sweden. The Union of South Africa was represented by observers only. On all maritime questions connected with safety at sea, seamen's rights, etc., the International Labour Office will act in close collaboration with the new organisation.

Lord Hyndley, chairman of the National Coal Board, stated in London on Thursday last week that the industry's targets could be reached only if the agreement to work extra hours was extended until at least the end of next winter. The miners' leaders had agreed, and he was sure the men would consent at the forthcoming national delegate conference to consider the matter. Even with extra hours there would have to be, he added, a further increase in output per man-shift and less absenteeism.

With the object of encouraging the recruitment of boys from non-mining areas, the National Coal Board is setting up about 80 residential training centres similar to those at Durham. The centres are intended to ensure that the recruits are well looked after while training. The course will last for 13 weeks, and the centres will be under the control of wardens and youth officers. Trainees will receive free maintenance, three meals a day, and the same rates of pay as those in non-residential centres. They will then go to a colliery to be trained for a specialised job by a qualified official. A specialised course for these officials on "how to receive a boy seeking employment" is now being held at Nuneaton Staff College.

According to official figures, absenteeism in the coal-mining industry was slightly less in the week which ended on March 6 than in the previous week. Voluntary absenteeism among colliers at the coal face was 7·57 per cent.; in the week which ended on February 28, it was 7·88 per cent. and in the week which ended on March 8, 1947, 11·98 per cent.

Of the stoppages of work due to industrial disputes known to the Ministry of Labour and National Service to have been in progress at some time in January, the coal-mining industry accounted for 99, involving nearly 10,000 colliers and resulting in an aggregate loss of over 15,000 working days. In all the industries covered by the Department's statistics, 173 disputes were reported as beginning in January. In addition, seven stoppages which began before January were still in progress at the beginning of that month. The approximate number of persons involved during January, in these 180 stoppages, including persons thrown out of employment at the establishments concerned, though not themselves parties to the dispute, was nearly 33,000, and the aggregate number of working days lost, during January, was about 82,000.

The Trade Union side of the Admiralty Shipbuilding Trades Joint Council have applied for a substantial increase in the wages of craftsmen and semi-skilled and unskilled workers employed in Admiralty shipbuilding establishments. The claim is for increases of 6*d.* an hour for craftsmen and 5*d.* an hour for semi-skilled and unskilled persons which would bring the craftsmen's weekly wage up to 6*l.* 6*s.*, that of the semi-skilled person up to 5*l.* 9*s.* 4*d.*, and that of the unskilled operative up to 5*l.* 8*s.* 4*d.* The unions also desire the national bonus and the basic wage to be consolidated.

A strike of women jack-frame tenters which started in the Bolton area and spread to other cotton-spinning mills at Farnworth, Leigh, Atherton and Tyldesley seriously threatened the output of cotton yarn, while it lasted. The women handle cotton in the last stage before spinning, and they ceased work because they were dissatisfied with their wages under the Aronson award. They asked for an increase of 10*s.* a week. After being assured by officials of their union that steps would be taken to open negotiations with the employers for a review of the wage question, the women at Bolton who began the strike agreed to restart work.

A partial unofficial strike of London employees of the Ministry of Works affected several Departments of the State, the House of Commons and, to some extent, Buckingham Palace. Its planners did not deserve to succeed, because a majority of the unions represented on the Ministry of Works District Joint Industrial Council did not take an active part in it. The men who ceased work claimed that the rejection, by the Treasury, of their application for a wage increase from 4*l.* 17*s.* 6*d.* a week to 5*l.* 10*s.* a week was unjustified.

The insufficiency in both numbers and quality of the labour force employed in the coal mines is one of the most serious problems facing Poland to-day. Although the number of miners increased from 122,500 to 199,900 between August, 1946, and August, 1947, and the numbers of highly-skilled workers rose during the same period from 5,472 to 6,807, the total labour force is still less than what is considered necessary to achieve the target laid down in the three-year plan. To achieve the target, a further 11,000 colliers and 526 skilled men will be required. This situation, it is explained in the *Review* of the International Labour Office, is largely due to bad housing conditions and the rapid turn-over of workers, many of whom have left the mines to take up work on the land or in the building industry.

In order to remedy this state of affairs, the competent authorities in Poland have taken a number of different measures. Firstly, in order to retain men in the mines who are already working there, efforts are being made to improve housing conditions; wooden bungalows are being built and existing houses restored. Priority is being given to miners for flats which become available. Overtime rates have been increased. Finally, in order to attract the greatest possible number of persons to the industry recruitment offices have been opened in Czczecin (Stettin) and Dziedzice; and displaced persons returning to Poland are offered special advantages to encourage them to take up work in the coal mines, such as free meals, longer holidays, and supplies in kind on a larger scale than those given to other people. Special courses for vocational training have been organised.

CENTRALISED RIPPLE CONTROL ON HIGH-VOLTAGE NETWORKS.*

By T. W. Ross and R. M. A. SMITH.

THE term ripple control is used in this country to describe remote control by alternating currents of audio frequency, which are superimposed on power networks. Although this system was introduced in the early part of the century, it is only during the past ten years that its application to large high-voltage networks has been seriously considered. On such networks superimposed alternating current at a frequency which differs from the power frequency must be used for remote control. The frequency employed must also enable the control currents to be transmitted and transformed through the power transformers without excessive losses. In general, a band of frequencies in the audio range has been found to answer the purpose.

The method by which the signal currents are injected is perhaps the major problem in applying superimposed control to high-voltage networks. This problem is largely economic and is bound up with the means of access to the network at the central station, and the size and the protection of the injection equipment. It is now used to inject in parallel with the whole network and improvements have been made whereby the size of the equipment has been reduced. In particular, the power lost in the tuning coupling circuit, which may, in certain conditions, account for 98 per cent. of the amount generated for signal purposes, has been cut down.

Essentially a centralised ripple control system, such as is very useful for the control of off-peak loads and street lighting, must be applicable to a network without interference with its operation and without serious modification in the power plant or switchgear. It must not employ frequencies which are so high that the attenuation of signal strength is detrimental or so low as to be too close to the power frequency. Frequencies lower than 400 cycles per second are too close to the higher voltage harmonics of the power frequency and may introduce difficulties in the receiving relays, while those above 1,000 cycles per second become liable to attenuation, especially on high-voltage overhead systems and on underground networks where cables with separately screened cores are used. In practice, the working range is generally between 400 and 800 cycles per second. A centralised control system should not be affected in any way by the presence of the large number of relays, running into many thousands, required for its operation. Some relays are believed to have an impedance at ripple frequency of 5 ohms, representing an impedance of 0·005 ohm per 1,000 relays. This approximates to the impedance of a 230-volt network with a maximum load of 20 MW. As the relays are connected in parallel with the system load, their number is therefore a governing factor in designing the injection equipment. It follows that it is desirable that the impedance of each relay should not be less than 100 ohms; otherwise, as the system is extended, the injection plant may become overloaded and the signal will fall below the minimum necessary for satisfactory operation. Further, it is most desirable that the apparatus should be designed, rated and built in accordance with the standards established for power equipment.

In designing ripple control equipment for any given power system the amount of power that must be injected in order to produce the desired signal voltage level must first be determined. This necessitates a determination of the effective audio-frequency properties of the power plant and network load. The characteristics of the system components having been found, the analysis necessary to determine the amount of ripple current that has to be injected to produce a given minimum ripple on the network and the nominal ratio of maximum to minimum ripple voltage over all the low-voltage networks can follow the principles usually adopted for fault-current evaluation. The method used, however, must be vigorous in order to take account of the resistive, inductive and capacitive components which should be adjusted for ripple-frequency values. Based upon an ordinary single line diagram of the high-voltage network, upon which all generators, reactors and bulk-supply connections must be included, an equivalent single-phase network may be drawn into the ripple-frequency impedances of all the major components indicated in complex nomenclature. The distribution of the ripple current throughout the network can then be determined by a calculating board or algebraically, and the ripple voltage level, which is the product of the ripple current and the resistance of the power load, calculated.

Prior to 1937 the only practicable method of injecting the ripple current into the high-voltage network was through transformers in series with individual radial feeders. The portions of the network to which these feeders were connected were then "rippled" consecutively. Although this method produces a high signal strength on a small section of the network with a comparatively small generator it is costly to install. It is also difficult to apply on complex networks and to find space for the large series transformers, which are usually required. The introduction of receiving relays, which will operate at one volt or less, enables a smaller generator to be used. The employment of the parallel-injection system, whereby the ripple signal can be propagated over the whole network simultaneously was thus encouraged. In the first of such installations employed in this country the output from the ripple generator was fed through a tuned reactor and condenser on to the low-voltage auxiliary or substation 'bus-bars, which were connected to the high-voltage network through one or more transformers. This arrangement, however, suffered from the disadvantages that a very high signal strength was required on that particular low-voltage network and that the ripple losses in the low-voltage network and in the step-up power transformers were high. Taken together these gave a ripple-injection efficiency of not more than 2 to 3 per cent.

The first improvement was the exclusive use of a power transformer for injection purposes. This avoided the loss due to the low-voltage network, but did not appreciably reduce the transformer losses. The employment of Litzendraht wire in the construction of the transformer and the tuning coils reduced the high-frequency copper loss, but as the transformer had to

Fig. 1.

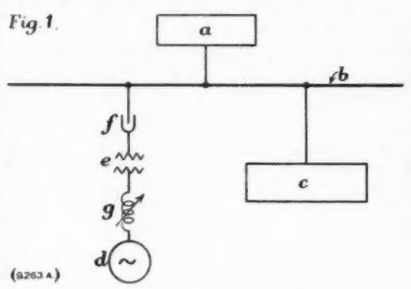


Fig. 2.

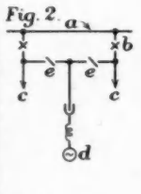
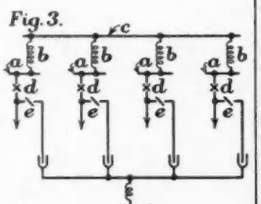


Fig. 3.



be designed primarily for direct connection to the 50-cycle network the improvement was not great. The next stage was the introduction of high-voltage coupling condensers, as shown in Fig. 1. In this diagram the power sources are indicated at *a*, the high-voltage 'bus-bars at *b*, and the high-voltage feeders to the network at *c*. The ripple generator is shown at *d* and the high-frequency transformer and high-voltage condenser at *e* and *f*, respectively. A tapped tuning reactor is indicated at *g*. As will be seen, a transformer was still used. It could, however, be designed for ripple-frequency duty only, so that its size and its losses were reduced. The injection efficiency was therefore raised to about 15 to 20 per cent. As this circuit was used for control schemes in which a different ripple frequency was employed for each signal, a tuning reactor with a tapping for each frequency had to be provided. It was therefore necessary to have selector contactors for tap-changing and, in order that these might be of the ordinary industrial type, the high-frequency transformer was introduced. With the advent of schemes using a single frequency per network, the tapped reactor was no longer required and the transformer could be connected between the generator terminals and a fixed reactor.

As this transformer had only to deal with the kilovolt-ampere output of the generator, and not with that of the resonantly-tuned reactor and condenser, its size could be reduced. Consequently, its losses were less and the injection efficiency was increased to about 40 to 50 per cent. The lower loss in the injection circuit had the further advantage that it reduced the variation in ripple-voltage with the output current, so that frequently an automatic voltage regulator for the generator was unnecessary.

Parallel injection equipment is generally quite easily accommodated in the usual switchgear layout. An ideal arrangement is to provide a circuit-breaker solely for ripple-control purposes as this gives adequate protection to the injection plant. In 95 per cent. of the cases, however, physical limitations in the switchgear on the cost of the high-voltage circuit breakers militate against this practice. Except for the very largest installations it is customary to use one of the substitute arrangements which have been devised for this purpose. The essential requirements for such schemes are full protection against power faults on the injection circuit, permanent and reliable connection between the injection circuit and the power system, and provision for the disconnection of the injection circuit from the power system without interfering with the operation of the latter. Fig. 2 shows the principle of the substitute arrangement in its simplest form as applied to a single 'bus-bar. The station high-voltage 'bus-bars are shown at *a*, while the circuit-breakers, *b*, are the existing ones controlling two outgoing feeders, *c*. As will be seen, the ripple-generating and injection circuit, *d*, is tied into each feeder circuit through two interlocked isolating switches *e*. For indoor use standard oil-immersed switches with a through-fault capacity of 250 MVA at 6·6 or 11 kV are employed. Where a higher through-fault capacity is necessary out-of-door air-break switches have to be used and these can be conveniently accommodated on the roof of the small building in which the injection equipment is housed. Another method of connection is shown in Fig. 3, where sections of the feeder 'bus-bars, *a*, are tied together through reactors, *b*, to the main station 'bus-bars, *c*. The feeder circuit breakers and isolators are indicated at *d* and *e*, respectively, and the ripple-generating and injection circuit at *f*. This is a very suitable arrangement from the ripple control point of view, as the reactors help to reduce the losses of signal current into circuits or apparatus connected to the main 'bus-bars. The tied points on each section need not be duplicated, since in the event of one injection circuit-breaker being open the amount of signal current which would flow through one reactor from the other groups in parallel would usually suffice for signal purposes.

On interconnected networks some of the control current may flow from one network to the others. This "spillover," as it is termed, not only involves loss of signal current, but may cause interference with the sending of signals or with ripple relays on those other networks. Its comparative magnitude is governed by the impedance of the interconnecting links. The most practicable means of avoiding interference from this cause, which is particularly noticeable if the same, or similar, frequencies are used on more than one network, is the use of different frequency channels on adjoining networks. It is therefore of paramount importance that the ripple frequency should be accurately controlled. The ideal method of doing this is to drive the ripple generator by a direct-current motor with an automatic frequency-responsive speed regulator. This regulator is a comparatively simple induction relay, which is connected to a double electrically-tuned network in such a manner that it controls the speed of the motor to within $\pm 0{\cdot}15$ per cent. This not only allows the use of sharply-tuned relays, but is a guarantee that spill-over signals do not encroach on the frequencies allocated to adjoining networks.

The function of the receiving relay is to perform some control operation, such as the switching of street or shop-window lighting and domestic hot-water heaters, in response to the ripple signal. Generally, these relays are designed to deal directly with heating loads up to 3 kW and lighting loads up to 1 kW, auxiliary contactors external to the relays being used for higher loads. Some relays perform the switching entirely from the ripple energy, but more usually an auxiliary relay, energised from the power supply through the ripple relay contacts, is employed. When auxiliary relays are not used, amplification of the ripple energy is necessary and this is usually effected by polarised mechanically-tuned reeds, which vibrate against the edge of a serrated wheel and cause it to turn in one direction or the other, depending on which reed is vibrated by its particular ripple frequency.

The number of ripple frequencies is limited by the necessity of avoiding the odd harmonics of the power frequency, which might interfere with the relays, and by limitations in the selective characteristics of the relays themselves. These characteristics, however, can be improved by connecting a non-linear resistance, such as a metal rectifier or metal filament lamp, so that the effective magnetising force of the operating coil is limited. To obtain the maximum control, the relay coil is indirectly connected to the tuning inductance through an inductive coupling, thus reducing the power-frequency component which would otherwise lower the efficiency of the non-linear resistance. Non-linear resistances do not, however, improve the selective properties of the tuned electrical circuit, but are effective only when the relay has an additional mechanically-tuned feature. This additional tuning is provided by

* Paper read before the Transmission Section of the Institution of the Electrical Engineers on Wednesday, February 11, 1948. Abridged.

relays of the polarised-reed type, although the improvement is dependent upon the amount of mechanical work the reed has to perform. This work can be reduced to a minimum by interfering as little as possible with the natural resonance of the reed.

Improved selectivity, in addition to providing more signal channels, also renders the relays less susceptible to interference from harmonics of power frequency or other parasitic voltages. On 230-volt mains, however, the voltage magnitude of the harmonics, other than the odd harmonics of the power frequency, seldom exceed 0·3 volt. Allowing for improved relay characteristics, it is still impracticable to provide for more than, say, 24 frequency channels, and one method of avoiding interference is to set aside a number of the channels for "unlocking" the receiving relays during signalling operations, one channel being allocated to each adjoining network for this purpose. It is, however, more convenient to employ a different ripple frequency for each network. Individual signal operations would then be carried out by some form of discriminating code without any fear of interference. Assuming that there is only one ripple frequency per network, selective signalling can be carried out by time-interval codes, pulse-counting codes or low-frequency periodic impulsing, the choice being largely determined by the size, simplicity and cost of the relay mechanism.

Relays of the time-interval code type consist of a ripple receiving element, which starts and stops a small synchronous motor. The latter drives some form of contact assembly, which is designed so that the contacts are opened or closed only in response to a given time interval between two impulses of ripple current. Relays of the pulse-counting code type operate on the step-by-step principle, each impulse of ripple current notching the relay mechanism one step forward. When the desired position has been reached, a pause in the code of impulses allows sufficient time for the operation of a delayed action auxiliary relay, which may be of the thermal type. Relays of the low-frequency oscillating type operate on the principle that comparatively small unidirectional forces applied to a pendulum in resonant periodic time intervals will cause it to swing through successively increasing angles. In practice, a mechanically-balanced and pivoted magnetic armature, which is controlled by a hair-spring, is substituted for the pendulum. The mass of the armature and the strength of the spring are proportioned so as to give the desired period of operation. Energy is applied to the operating coil of the relay at periodic time intervals corresponding to the period of oscillation of the armature, and, when sufficient impulses have been applied, the armature builds up amplitude to operate its contact which, in turn, energises the operating coil of a batching-type auxiliary contactor so as to perform the final load-switching operation.

Perhaps the most profitable use to which centralised ripple control can be put is to deal with off-peak domestic loads, especially water heaters. This apparatus is one of the best consumers in the domestic field and, provided the maximum demand is not increased by its use, is a profitable source of revenue; so much so that the cost of off-peak load control can be justified. If, for example, the maximum demand cost increment per kilowatt is 3*l*. 10*s*. 0*d*., every 3-kW heater represents a minimum potential addition of 10*l*. 10*s*. 0*d*. to the demand charges at peak load. Such a heater would consume, say, 4,000 to 5,000 kWh per annum, equivalent in revenue to 8*l*. to 10*l*. At off-peak time, it would therefore be a desirable contribution to the domestic load factor and the profits of the supply authority. At least 8*l*. per water heater could therefore probably be invested in ripple control. Although the water heater is the only part of the domestic load which at present is looked upon as suitable for off-peak control, space heating often creates the highest peaks. There are, however, many difficulties in regulating the space heating load, the principal one being the impracticability, from the consumer's point of view, of entirely disconnecting space heaters at times of peak load. It seems reasonably practicable, however, to reduce the consumption per heater at such times. One way of doing this would be to lower the voltage by means of a tapped auto-transformer under the control of a ripple signal. The secondary part of this transformer would be connected in series with the power or heating circuits of each consumer and could conveniently be rated at 10 per cent. of the installed capacity. This would give 20 per cent. reduction of the heating load without serious inconvenience to the consumer, but with distinct advantage in reducing the maximum demand.

INSTITUTION OF HEATING AND VENTILATING ENGINEERS.—Preliminary arrangements have been made for holding this year's summer meeting of the Institution of Heating and Ventilating Engineers at Bournemouth from Monday, June 21, to Wednesday, June 23. Further details will be announced to members in due course.

FATIGUE TESTS OF MARINE SHAFTING.

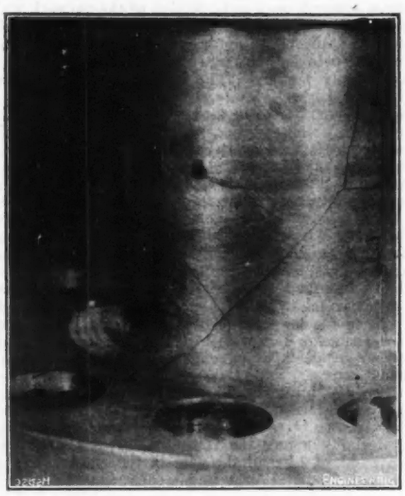


FIG. 22. FATIGUE CRACK IN SHAFT NO. 3.

TORSIONAL-FATIGUE TESTING OF MARINE SHAFTING.*

By S. F. DOREY, C.B.E., D.Sc., Wh.Ex.

(*Concluded from page* 288.)

IN view of the low fatigue strength obtained for the welded shafts, the Admiralty decided to have tests carried out on forged shafts, and three were tested for them. The results are shown in Table II. The

TABLE II.—*Forged Shafts.*

Test shaft No.	Ultimate Tensile Strength of Shaft Material, Tons per sq. in.	Ratio of Shaft Diameter to Fillet Radius.	Torsional Stress, Lb. per sq. in.	No. of Cycles.	Remarks.
3	35	6·5	±10,000	7·2×10⁶	Crack formation commenced at slight tool mark in fillet (Fig. 22).
6	30·5	5 approximately	± 7,500 ± 9,000 ±10,500 ±12,000 ±13,500 ±15,000 ±16,500	1×10⁷ ,, ,, ,, ,, ,, 3·96×10⁶	Cracks originated in the keyway at the nodal point of the shaft. (Fig. 23).
7	33	4·875	±10,500 ±12,000 ±13,500 ±15,000	1×10⁷ ,, ,, 8·09×10⁶	Cracks originated in the keyway at the nodal point of the shaft. (Fig. 24).
8	30·5	8	±10,000 ±11,500 ±13,000 ±14,500 ±16,000 ±17,500	1×10⁷ ,, ,, ,, ,, 8·1×10⁶	Cracks originated in the coupling fillet (Fig. 25).

material employed for test shaft No. 3 had a tenacity of about 35 tons per square inch, and in the case of the other two forged shafts, 28 to 32 tons per square inch. The forged test shafts were identical with the welded shafts as regards dimensions, except that the fillet radii in the case of test shafts Nos. 6 and 7 were approximately 2 in. instead of 1½ in. In view of the results obtained for specimens Nos. 6 and 7, the author decided to carry out an additional test, on shaft No. 8, with a view to ensuring that fracture would take place initially in the coupling fillet and not in the keyway. For this purpose, a shaft was forged to represent an intermediate shaft of normal merchant-service design, the shaft being solid, with coupling fillet radii of one-eighth the diameter of the shaft, i.e., $1\frac{7}{32}$ in. In this test specimen, a solid key was fitted to a flat milled on the shaft journal, as already described.

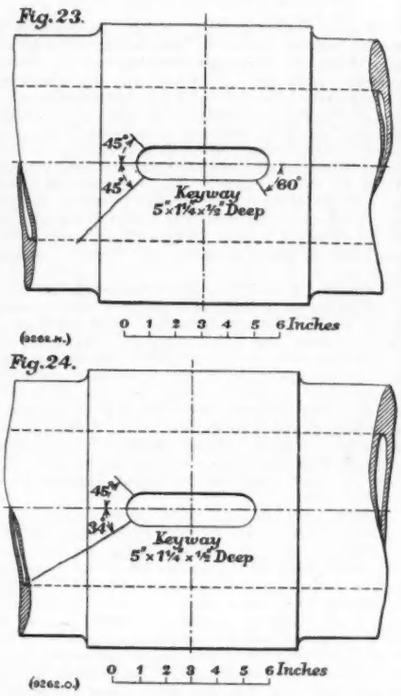


Fig. 22 indicates the fatigue crack which originated in the fillet of test shaft No. 3. Material was taken from this shaft and tested on a torsional-fatigue testing machine at the National Physical Laboratory, using specimens of 0·5 in. diameter. The torsional fatigue limit so determined was ±10 tons per square inch. In the case of test shaft No. 6, a different technique was used. Large-scale fatigue tests are very expensive, and the question arises whether it is really necessary to employ the same technique as used hitherto for small specimens. In the latter case, about six specimens may be used to determine the curve of number of stress cycles to rupture, and, from this curve, the fatigue limit. For small specimens of steel it has been found that, provided the fatigue stress is just low enough to permit the specimen to withstand 10^7 cycles of stress, a very great number of cycles of this stress can be endured. To reduce, from six to one, the number of test pieces required in large-scale testing, it was planned to commence testing at a low fatigue stress and after each 10^7 cycles to increase the stress in small increments until failure occurred. This procedure was also adopted for test shafts Nos. 7 and 8.

Automatic control of stress, to replace manual control, was also applied to shafts Nos. 6, 7 and 8. Figs. 23 and 24 illustrate the cracks formed at the keyway for these former two specimens, respectively. The diameter of the specimens at the keyway was 10½ in., so that the nominal stress was, for all tests, approximately 70 per cent. of that on the section of 9¾ in. diameter. When test shaft No. 6 had been subjected to 5×10^6 cycles at a stress of ± 13,500 lb. per square inch, the top half of the bearing was removed, and, after a thorough cleaning, the whole surface including keyways and fillets, was inspected for cracks under a magnifying glass; no sign of failure could be detected. After 7×10^6 cycles at ± 15,000 lb. per square inch, it was noted that a fall in frequency had occurred. The first visible sign of fracture was noticed after 396,000 cycles at ± 16,500 lb. per square inch., in the fillet adjoining the enlarged portion of the shaft forming the centre bearing. The top half bearing was then lifted and three cracks were noted, as indicated in Fig. 23.

Test No. 7 was carried out under somewhat similar conditions to test No. 6. From the experience obtained in the previous test, it was anticipated that fracture of the shaft would occur in the keyway. In consequence, the top half of the bearing was removed after 10^7 cycles of stress had been completed at ± 13,500 lb. per square inch, and again after $6{\cdot}51 \times 10^6$ cycles at ± 15,000 lb. per square inch. Careful inspection did not reveal the presence of cracks. The temperature

* Paper read before the Institution of Mechanical Engineers, London, on Friday, February 13, 1948.

FATIGUE TESTS OF MARINE SHAFTING.

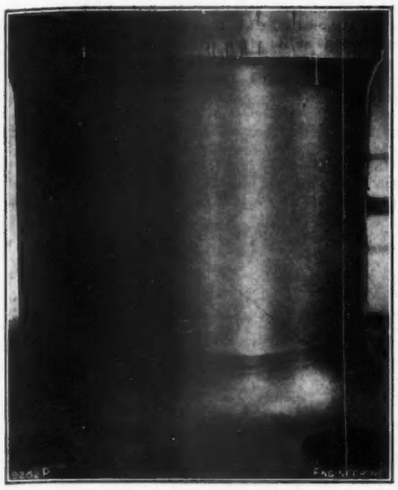


FIG. 25. FATIGUE CRACK IN SHAFT No. 8.

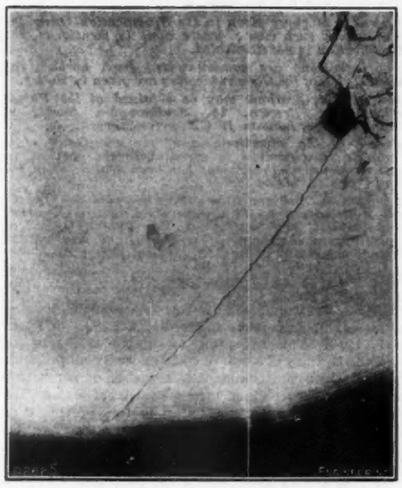


FIG. 28. FATIGUE CRACK IN MEEHANITE SHAFT A.

Fig. 26.

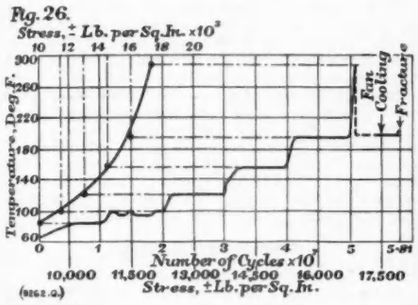


Fig. 27.

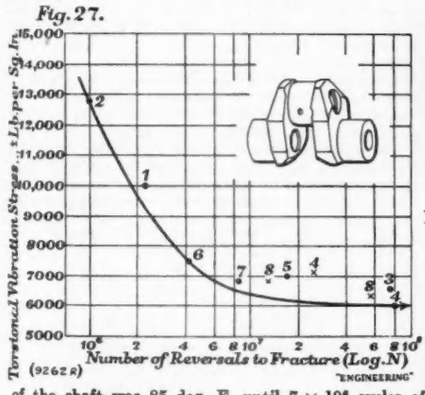


FIG. 29. FATIGUE CRACK IN MEEHANITE SHAFT C.

of the shaft was 85 deg. F. until 7×10^6 cycles of stress had been completed at $\pm$ 13,500 lb. per square inch, when it rose rapidly to 200 deg. F. No further notable increase in temperature occurred until $6{\cdot}9 \times 10^6$ cycles had been completed at a stress of $\pm$ 15,000 lb. per square inch, when a temperature of 320 deg. F. was attained. The shaft remained at this temperature until failure after $8{\cdot}09 \times 10^6$ cycles at $\pm$ 15,000 lb. per square inch. A fall in frequency was not noted until 8×10^6 cycles of stress had been run at $\pm$ 15,000 lb. per square inch.

As shown in Table II, the solid-forged test shaft No. 8 failed after $8{\cdot}1 \times 10^6$ cycles at $\pm$ 17,500 lb. per square inch, after having previously withstood 10,000,000 cycles at each of five lower stress ranges, commencing with $\pm$ 10,000 lb. per square inch. Fig. 25 shows the appearance and location of the fracture in the coupling fillet adjacent to the exciter. It is interesting to record that, when the stress was increased from $\pm$ 16,000 lb. per square inch to $\pm$ 17,500 lb. per square inch., the shaft surface temperature rose rapidly from approximately 195 deg. F. to 282 deg. F. This was accompanied by a reduction in the maximum stress on resonance of from $\pm$ 20,000 lb. per square inch for the cold shaft, to $\pm$ 16,500 lb. per square inch for the hot shaft. Cooling air from a fan was then applied to the shaft; the air reduced the surface temperature to approximately 200 deg. F. The maximum stress obtainable on resonance at this temperature was of the order of $\pm$ 18,000 lb. per square inch. The test was run off at this temperature, and the stress of $\pm$ 17,500 lb. per square inch was steadily maintained until failure occurred. Shaft surface temperatures were measured by means of thermo-couples, and also by temperature-sensitive wire resistance strain gauges applied to the shaft. Fig. 26 indicates the temperature variation in relation to the number of cycles, also to vibratory stress, from which it will be noted that a very rapid rise of temperature occurs during the application of the final stress of $\pm$ 17,500 lb. per square inch. Owing to the high temperatures reached during this final run, it was found desirable to supplement the strain gauges measuring shaft stress with an electromagnetic type of vibration pick-up measuring the tangential oscillation of one of the flywheels at a convenient radius. This pick-up had been calibrated previously while the shaft was cold, in terms of stress indicated by the strain gauges on the shaft.

Small polished test pieces, $\frac{1}{4}$ in. in diameter, cut from the forged material of this shaft, and tested in reversed torsion on the National Physical Laboratory's combined stress machine, gave a fatigue limit of approximately $\pm$ 9 tons per square inch, giving a value of about 1·17 for the overall factor, $\Delta = \frac{f}{F}$, where f represents the reversed torsional fatigue limit of a $\frac{1}{4}$-in. diameter polished specimen without stress concentration, and F represents the reversed torsional fatigue limit of a $9\frac{1}{2}$-in. diameter solid test shaft, with stress concentration due to a fillet radius of one-eighth of the shaft diameter, and with commercial smooth-turned finish, the fatigue strength being estimated from the results of the special testing procedure adopted. The results obtained with test shafts Nos. 6 and 7 would seem to show a value for Δ of about 2, for a sunk keyway with rounded ends.

For comparison with the results of the fatigue tests described in this paper, it may be of interest to mention the results of somewhat similar large-scale torsional fatigue tests carried out in Germany during the war for the German Admiralty.* The tests were carried out on separate but similar crank throws, having a pin diameter of 9·65 in., the crankpin forming the spring member of a two-mass torsional vibration system, and being clamped by its webs to two equal oscillating masses, with its pin co-axial with that of the machine. This arrangement was shown by Lehr and Ruef to approximate most nearly to actual service conditions, having regard to normal clearances usual in main bearings. Centrifugal forces provided the excitation, a pure reversed torsional couple being applied to one of the oscillating masses at a testing speed of the order of 1,000 vibrations per minute. The dimensions of the crank webs unfortunately were not given, but an idea of the design may be derived from the perspective sketch in Fig. 27. The crankpin was hollow bored about 50 per cent. on diameter, with a fillet radius of 0·59 in. The corresponding ratio of pin diameter to fillet radius (about $16\frac{1}{2}$) represents normal crankshaft practice. It will be noted that the crankwebs were heavily chamfered, and only about 40 per cent. of the crankpin diameter in axial thickness. The crank sections were forgings made to specification St.C.35,61, which requires a tenacity of 35 to 41 tons per square inch. Eight throws were tested and Fig. 27 shows the endurance curve obtained. The results for the various throws are numbered from 1 to 8, and the points marked with a cross indicate stress values artificially raised by previous fatigue testing at lower stresses. The endurance curve was drawn through the lower limit of the "scatter" region, and shows a limiting fatigue stress of $\pm$6,000 lb. per square inch. It is important to note that the number of cycles given in this diagram is the number actually required to fracture the shaft, and not the number to produce the first detectable fatigue crack. For example, in the case of crank No. 3, the first fatigue crack occurred after 7,000,000 cycles, but the final fracture did not take place until after 75,000,000 cycles. With the exception of cranks Nos. 4 and 7, all fatigue cracks commenced in the fillets. An interesting point brought out by this series of tests was that the fatigue strength seemed to be almost unaffected by the presence, in the pin and fillet surfaces, of numerous small flaws, only capable of resolution under the "Magnaflux" process, the theory being that such flaws mostly do not represent actual cracks, but are small groups of the finest slag inclusions. The effect of flaws in the form of cracks large enough, to be visible to the naked eye was not investigated.

To obtain some idea of size effect, a smooth test piece of St.C.35,61 of diameter 1·18 in. gave a reversed torsional fatigue limit of about $\pm$ 23,000 lb. per square inch, which is in good agreement with National Physical Laboratory results already quoted for test shaft No. 3. This comparatively high value, of course, must be attributed in some measure to the negligible stress concentration produced in a standard smooth test piece of this size. In considering the results given in Fig. 27 it should be remembered that the ratio $d : r$ for the fillet was 16·5, as compared with 6·5 for the author's test shaft No. 3, and it is considered that the difference in $d : r$ values could account, to some extent, for the different fatigue results obtained. A value of about 3·8 is indicated for the overall factor Δ, based on a diameter of 1·18 in. for the small test piece.

It has been mentioned previously that certain alterations were made in the large fatigue-testing machine, in order to test a number of cast-iron shafts, and as these were 6 in. in diameter, it is considered of interest to include the results in this paper. The shafts were of cast Meehanite, and, through the courtesy of Mr. R. B. Templeton of the Ealing Park Foundry, the test results are shown in Table III, on page 312. Figs. 28 and 29 indicate the crack development for test shafts A and C, respectively. Small-scale torsional fatigue specimens, $\frac{1}{4}$ in. diameter, gave a value of $\pm$ 7·7 tons per square inch for this material. It had been ascertained previously that reversed bending tests had indicated a fatigue limit of approximately $\pm$ 12 tons per square inch. It is difficult to assess with confidence a value for scale effect, but in these tests a value of about 2 is indicated for the overall factor Δ.

The results so far obtained with this large torsional-fatigue testing machine indicate clearly the overall reduction in fatigue strength in large shafts, due to stress concentration set up by the geometrical form of the stressed parts, to lack of homogeneity of the

* Lehr, E., and Ruef, F. *Motortechnische Zeitschrift*, vol. 5, page 249 (1943).

material, and to any size effect, if present. So far as size effect is concerned, the results obtained for mild-steel test shafts Nos. 6, 7, and 8, tested in the manner described, show that this effect may be very appreciably less than that given by other investigators when comparing test results over a considerably smaller

TABLE III.—*Meehanite Cast-Iron Shafts.*

Test shaft	Ultimate Tensile Strength of Shaft Material, Tons per sq. in.	Ratio of Shaft Diameter to Fillet Radius.	Torsional Stress, Lb. per sq. in.	Number of Cycles.	Remarks.
A	30	6·0	± 4,080	1×10^7	
			± 5,190	,,	
			± 6,300	,,	
			± 7,420	,,	
			± 8,530	$8{\cdot}15\times10^6$	Crack developed in shaft material, and spread in 45-deg. spiral into the fillet (Fig. 28).
B	30·5	6·0	± 8,500	$8{\cdot}16\times10^6$	Grain structure of shaft material coarser than shaft A. Several cracks developing.
C	31	6·0	± 7,000	1×10^7	
			± 8,000	$3{\cdot}65\times10^6$	Crack developed very rapidly (15 minutes), starting from fillet and proceeding as 45-deg. helix. (Fig. 29).

range of diameters. In the case of Meehanite cast iron, the limited evidence provided by the tests indicates that the overall effect is more pronounced than with mild steel. There is a whole field for future investigation in the determination of the effect of a variety of factors influencing the fatigue strength of shafting.

ANNUALS AND REFERENCE BOOKS.

International Mercantile Diary and Year Book, 1948.—The thirty-second annual edition of this year book, which the publishers describe succinctly as "the exporter's guide to Consular, Customs and postal regulations for all countries," has recently made its appearance. The book is divided into a number of sections the first of which covers Great Britain. This contains a great deal of information on commercial matters, such as export invoice requirements, Imperial Preference regulations, import duties, shipping documents, export credits guarantees, methods of payment, and marine insurance. After the section on Great Britain, every country in the world is dealt with in turn; first, the British Empire, which is arranged on a territorial basis, and then foreign countries, given alphabetically and followed, in each case, by their colonies and dependencies. The data given for each country include such matter as principal towns and cities and their populations, Consular addresses, principal banks, the currency used, weights and measures employed and tables converting them to British units, postal information, the nature of the import and export trade and other commercial information. A diary section giving a week to each page follows, and the book closes with a section on conversion and other useful tables and general information. The publishers are "Syren and Shipping," Limited, 26-28, Billiter-street, London, E.C.3. The price of the book is 25s., post free, and this includes a monthly copy of *The Merchant Shipper*, containing addenda to the Year Book, thus enabling subscribers to maintain the information up to date.

The British Corporation Register of Ships, 1947-8.—By force of circumstances, the 1947 edition of the *Register of Ships*, published by the British Corporation Register of Shipping and Aircraft, 14 Blythswood-square, Glasgow, C.2, could not be issued at the usual time and, therefore, has been brought more up to date and designated the 1947-8 volume. It contains all the usual features and, indeed, is back to the pre-war standard, except that certain surveyorships in ex-enemy ports are still indicated as vacant. The *Register* is issued only to subscribers, the terms of subscription being, to individuals and firms, six guineas for the first copy and three guineas each for additional copies; and to underwriting and marine insurance companies, etc., eight guineas for the first copy and four guineas each for additional copies. As the present volume is a combined one for 1947-8, subscribers to the 1947 edition will receive the periodical supplements throughout 1948 without extra charge.

"ENGINEERING" ILLUSTRATED PATENT RECORD.

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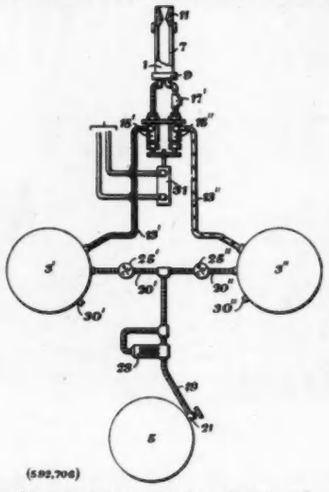
The date of the advertisement of the acceptance of a Complete Specification is given after the abstract in each case, unless the Patent has been sealed, when the word "Sealed" is appended.

Any person may, at any time within two months from the date of the advertisement of the acceptance of a Complete Specification, give notice at the Patent Office of opposition to the grant of a Patent on any of the grounds mentioned in the Acts.

AERONAUTICS.

592,706. Jet-Propulsion System. Aerojet Engineering Corporation, of Pasadena, California, U.S.A. (3 *Figs.*) May 7, 1943.—This invention relates to a system for controlling the flow of a pair of spontaneously combustible propellants into the combustion chamber of a reaction motor at a pre-determined mixture ratio throughout the entire throttling range. Reaction motors of this type are used for the jet propulsion of aircraft. The jet-propulsion system consists of a jet motor 1, two propellant supply tanks, 3′ and 3″, containing, respectively, a liquid fuel such as aniline and a liquid oxidising agent such as red fuming nitric acid, and an auxiliary tank 5 containing an inert gas such as nitrogen at high pressure. The jet motor 1 comprises a tubular body section 7 forming a combustion chamber with an injector 9 mounted at its forward end and a De Laval nozzle 11 at its rear end. The injector has different propellant injection passages which are connected to the respective propellant tanks



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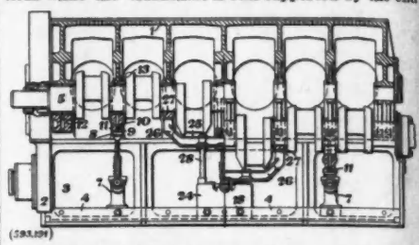
3′ and 3″, through the conduits 13′ and 13″. Each conduit contains one of a pair of synchronously operable valves 15′ and 15″ which are normally closed. One of these conduits includes a mixture-ratio adjuster 17′. The auxiliary tank 5 is connected through a main conduit 19 to two conduit branches 20′, 20″, which connect, respectively, to the two propellant-supply tanks 3′ and 3″. A valve 21 and a pressure regulator 23 are connected in the conduit 19. Check valves 25′ and 25″ are connected in the branch conduits 20′ and 20″. Safety plugs 30′ and 30″ are fitted in the walls of the respective propellant-supply tanks. A remote control hydraulic system 31 operates the two propellant.control valves 15′ and 15″, respectively. The control valves 15′ and 15″ are operated synchronously and form the throttle for the motor, while the proportions of fuel and oxydising agent employed are correctly set by the mixture-ratio adjuster 17′. (*Sealed.*)

INTERNAL-COMBUSTION ENGINES.

593,191. Engine-Repair Equipment. Davey, Paxman and Company, Limited, of Colchester, Essex, and E. P. Paxman, of Colchester, Essex. (4 *Figs.*) December 11, 1944.—This invention relates to equipment for use with internal-combustion engines, to enable a crankshaft to be lowered away from its normal operative position for inspection or repair purposes. It is intended more particularly for application to engines operating in confined spaces, such as in ships, and enables repairs and adjustments to be effected which might otherwise entail the complete dismantling of an engine. In the illustration, 1 indicates the crankcase of a multi-cylinder internal combustion engine. To provide space for lowering the crankshaft the engine is mounted upon an under-bed 2 upon which the ordinary crankcase 1 is fixed, and which includes a number of inspection doors 3 in its sides. A central channel-shaped support 4 extends throughout the length of the under-bed in a position vertically beneath the crankshaft 5, the arrangement of the channel being such that its sides project upward with its base fixed to the base of the under-bed. As a preliminary operation, the big ends of the connecting rods are disconnected from the crankshaft 5 and either removed altogether or temporarily secured in positions free from the crank shaft. The channel 4 supports jacks 7 the heads of which have flanges 8 through which pass bolts 9, engaging tapped sockets 10 in the inter-crank bearing caps 11, which can thereby be detached from their operative positions while the crankshaft is still supported by the end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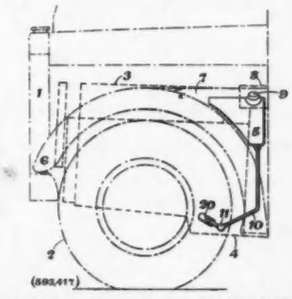
bearings 12 and the end plates of the engine housing. After the bearing caps and the lower halves 11 of the main bearings have been removed, the upper halves 13 of these bearings are also removed. The crankshaft is then ready to be supported by a cradle consisting of a body 24 movably mounted upon the channel 4 but able to be locked in the correct position by pins 18. Supported above the body 24 is the cradle proper 25, which extends lengthwise and has upwardly-directed arms 26 terminating in curved supports 27 to seat beneath two portions of the crankshaft 5. The cradle is supported on vertical guide pins 28 which slide in the body 24 and in the centre of the body is a screw jack. When the end bearings 12 and the end plates of the engine housing have been removed, and the crankshaft has been freed from engagement with other units, the screw jack which supports the cradle 25 can be operated to lower the cradle and crankshaft. (*Accepted October* 10, 1947.)

MOTOR VEHICLES.

593,417. Lubricating Systems. Leyland Motors, Limited, of Kingston-on-Thames, Surrey, and V. W. Pilkington, of Leyland, Lancashire. (5 *Figs.*) September 20, 1944.—The purpose of this invention is to facilitate the periodical oil filling of the engine. An oil pump driven by the engine draws oil from the sump and supplies it to the working parts of the engine, from which it drains back to the sump in the usual way. To make up for losses, the sump is supplied with oil from a reservoir at a higher level, through a valve actuated by a float. The front end of a motor vehicle, including the radiator 1, a front wheel 2, the engine 3 and its oil sump 4, is shown in chain-dotted lines. A replenishing oil container 5 is mounted on the wing 6 of the front wheel 2, the container conforming in shape to the wing and being enclosed by sheet metal 7 extending horizontally and vertically from the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wing 6. In this enclosure is a hinged flap 8 giving ready access to the filling opening 9 of the container 5. A pipe 10 connects the container 5 with the sump 4, and ends within the sump at a float-operated valve indicated generally by 11. The inlet pipe of the oil pump is supplied through hinged tubes and a filter carried by the float 20. The float keeps the pump inlet near the surface of the oil and thus away from sediment in the bottom of the sump. When the level of the oil in the sump drops, the float 20 also falls, and opens the valve 11, permitting oil to flow into the sump from the container 5 until the level is restored. Thus the oil is maintained at the working level during the interval between servicing inspections, which may be daily, weekly, or as may be found convenient, the volume of the container 5 being designed to hold enough replenishing oil for the period contemplated. (*Accepted October* 16, 1947.)